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THE AIR FORCE COMMUNICATIONS SERVICE

WESTERN UNION salutes the Air Force Communications Service (AFCS) on the day of its activation, July 1, 1961.

Western Union also congratulates Major General Harold W. Grant, formerly Director of Telecommunications, Headquarters, USAF, on being selected to head the Air Force's newest—its nineteenth—Major Air Command. General Grant's outstanding leadership and contributions to the progress of Air Force Communications during his 29 years of association with the communications-electronics field have earned for him the highest respect of the telecommunications industry.

Congratulations to the Air Force itself also are in order for its foresight in establishing the Air Force Communications Service. This new organization will bring a unified approach to the total Air Force operational communications requirement.

Initially, on July 1, the AFCS will assume communications responsibilities of the former Airways and Air Communications Service (AACS), plus the communications responsibilities of the Military Air Transport Service (MATS), the Air Charting and Information Center, the Air Force Finance Center, and the Carribbean Air Command. On a phased basis over the next two years, the AFCS will assume responsibility for operating and maintaining communications for other Commands. AFCS, at that time, will then operate and maintain both inter- and intra-unit communications *for the Air Force as a whole*, plus the Air Force's terminal and enroute navigational aids—which collectively comprise most of what is known as the Aerospace Communications Complex (AIRCOM).

More specifically, the AFCS will operate USAF-government owned and commercially leased long-haul point-to-point wire, cable and radio means of providing voice and record types of service. With regard to interbase communications, it will operate communications for providing intelligence, weather and command, and control of the Air Force weapon system world-wide. As for intrabase communications, AFCS will operate telephone and telegraph systems, closed circuit TV, fire-crash systems, maintenance expediter systems, etc.

In short, the Air Force Communications Service will provide capability through which the Air Force can exercise command and control of global Aerospace forces.

As the operator of Air Force communications, the Air Force Communications Service will serve as a single point of contact on day-to-day operational matters with the recently established Defense Communications Agency. (According to the Department of Defense, the agency was organized to provide over-all DOD operational control and supervision of the long-haul communications facilities *operated* by the separate military services. Grouped together for over-all DOD management, the separate facilities of each Service are known collectively as the Defense Communications System.)

General Thomas B. White, who retired as Air Force Chief of Staff June 30 and was succeeded by General Curtis E. LeMay, had listed "an improved system of communications" as one of his ten most important developments required by the Air Force. In a recent

statement, General White said: "In the Air Force our vast and modern communications network acts as a nerve system which binds our far-flung combat units into a single powerful integrated global fighting force."

As General White also stated: "The security of our nation and perhaps the free world could well depend upon the reliability and responsiveness of our present and future communications systems."

The Air Force's over-all communications capability is described in large figures: 40 million printer messages yearly—500,000 miles of wideband channels—5 million miles of leased lines—90 million punch cards annually for logistic support—the Plan 55 Global Communications System—and more.

The Air Force, in addition to being the largest contributor of leased communications networks and switching facilities to the Defense Communications System, is by far the largest single military user of leased communications within the Department of Defense.

With the establishment of the Air Force Communications Service, we in Western Union envision continued great progress in Aerospace Communications. It is our firm desire to aid in every way possible.

DANIEL T. BROSNAN joined the Western Union Commercial Department in 1937, and transferred to the Engineering Department in 1940. After 38 months' service with the U. S. Army Signal Corps in World War II, he returned to Western Union and continued his engineering education, receiving the B.E.E. degree from the Polytechnic Institute of Brooklyn in 1953. After several years of work in connection with d-c telegraph transmission projects, he was assigned to the Plan 55 project where he was involved with the packaging, manufacture, and production testing of electronic equipment, and the design of general switching center maintenance test facilities. Subsequently, he held similar assignments for the Plan 57 and Plan 59 projects. He has also been engaged extensively in field testing prototype switching center installations of which the Honolulu installation described in the paper is representative. Mr. Brosnan is a member of Tau Beta Pi and Eta Kappa Nu.

DANIEL T. BROSNAN, Project Engineer, Comlognet

Plan 59 Automatic Message Switching System

THE first of a series of new automatic message switching centers designed to provide a modern high-speed message switching system for the United States Federal Aviation Agency (FAA) was cut over on December 21, 1960, at Honolulu, Hawaii.

As finally evolved, the system, known as Plan 59, utilizes system components of both the Plan 55[1] and the later Plan 57[2] switching systems, together with certain additional features necessitated by the nature of FAA message format and routing requirements. Switching centers are of the "message storage" variety, wherein messages received at a receiving position are switched (automatically) to that sending position handling onward sending to the destination address. Intracenter switching and message handling is accomplished over cross-office circuits distinct from incoming and outgoing lines. The arrangement is such that the receiving position receives from an incoming line and sends cross-office to the sending position which in turn sends out to the sending line. The general theory and background of cross-office switching has been dealt with in detail by previous writers[3] and will not be covered here.

SYSTEM REQUIREMENTS

Plan 59 switching centers are required to handle, on a fully automatic basis, national and international teleprinter message traffic conforming to the message format of the International Civil Aviation Organization (ICAO). Operationally, the switching centers will be part of the Aeronautical Fixed Telecommunications Network (AFTN).

Center Routing

An important system requirement specified that in the case of multiple-address messages, no segregation of routing indicators take place. This means that all address routing indicators contained in the address section of the message as originated must appear in the message copy received by each addressee. At first glance this might not seem to have been a difficult requirement to meet. However, when considered in conjunction with other factors it becomes evident that a system of considerable flexibility is required to cope properly with it.

Perhaps the most important consideration in this regard is the fact that the originator of each message to be relayed through the Plan 59 center may have several circuits available, only one of which terminates in the center. A multiple-address message received at the center from such an originator may already have been transmitted to one or more of the addressees directly from the point of origin. Unless means are provided at the center to recognize the addresses which have been so handled, multiple copies of messages will be delivered to addressees.

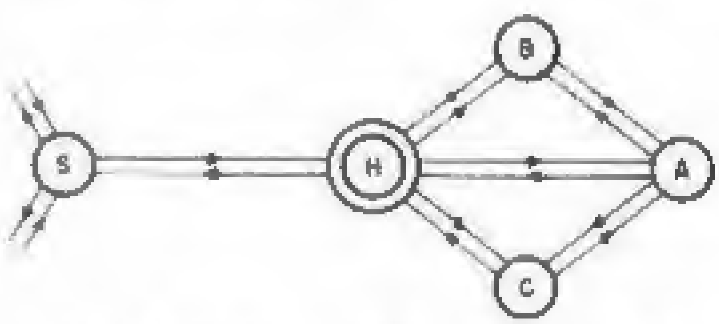

Figure 1. Illustrating alternate channels available to "other centers"

A hypothetical case will illustrate this. In Figure 1 point A has circuits to B, C, and H. A originates a message addressed in multiple to B, C, and S, the latter a circuit off automatic center H. The message is sent to B, a manual switching center, where the C and S routes are noted by an attendant and disregarded since it is realized that A has other circuits for these routes. The message is sent to C,

where the B and S routes are noted and disregarded for similar reasons. Lastly, the message is sent to H, an automatic center where, if similar discrimination were not provided by the automatic equipment, the message would be switched and transmitted not only to S, but also again to B and C. The confusion is compounded if S also is an automatic center, since it too would switch the same message back through H, to B and C. Additional ramifications will undoubtedly occur to the reader. At any rate it is obvious that the multipled load of duplicate messages would soon bog down facilities while the receipt of two or three copies of the same message over different circuits would be intolerable.

To prevent such occurrences, the "center routing" concept was evolved. Center routing considers each point sending into a line receiving position in a Plan 59 switching center (but not way receiving positions as will be explained later), an "other center." These distant points are assumed to have at least two outgoing circuits, only one of which terminates in a line receiving position in the center. Based upon traffic studies, a determination can be made for each line receiving position as to how each address routing indicator appearing in the address section of the received tape is to be handled. This information is made available automatically when the line receiving position is connected to the automatic switching director during the time the desired cross-office connections are being set up.

QSP Messages

As is usually the case where radio circuits are employed extensively, it is often necessary for the originator or an intermediate relay point to route messages over alternate circuits when atmospheric conditions render the established circuit unusable. Such messages may contain routing indicators in the address section which would be treated normally as "no action" when received in the switching center. The center must be capable of detecting such messages and routing them to their proper destinations.

To distinguish such alternately routed messages from normal messages, AFTN format requires that a diversion section "QSP-" be inserted in the message address section by the originator or the previous center which initiated the alternate routing action. QSP is one of several agreed upon Q signals used in international radio traffic handling and has the meaning "will you relay to —." The diversion section will result in an alarm when the message is received at a line receiving position in the center and will alert an attendant who will take the necessary action to insure proper routing.

For this purpose the line receiving position is equipped with a manual routing panel containing a push button for each of the 80 maximum destinations to which the position is capable of switching. This panel allows the attendant to scan the tape and select manually the proper destination for each routing indicator in the message address section, independently of the center routing program.

In addition to its use in handling QSP messages, the push-button panel serves also as a fallback for the director in the event some emergency disables the latter. In such a case messages may be routed manually until director operation is restored.

Also, when an alarm is occasioned in the line receiving position by a message text garbled so as to render automatic director switching impossible, the message can still be routed to its proper destinations via the push-button panel if after inspection by an attendant such a step is considered feasible.

Routing Indicator Format

The cross-office switching equipment in a Plan 59 switching center must be capable of processing address routing indicators consisting of from four to eight characters, in accordance with AFTN format. In addition, certain single-character and 3-character routing indicators must be read in connection with switching to closed-out way stations from the way intercept or way spill-over position, as described under Switching System Operation.

The first four characters of the routing indicator consist of the ICAO 4-letter location indicator assigned to the location of the aeronautical fixed station serving the destination. The next two characters comprise the 2-letter abbreviation identifying the particular organization served by the fixed station. The final two characters are passed by the automatic equipment, but not read or stored, since they are intended merely for internal routing within the addressee organization. Should the routing indicator be longer than eight characters, an alarm will be activated when the ninth character is sensed.

Priority Messages

AFTN format calls for the use of a priority indicator directly preceding the routing indicators in the address section of the message. These priority indicators consist of 2-letter groups which determine message precedence. No special action is required by the switching center on any but the "SS" priority indicator, which is concerned with distress messages and messages involving the safety of human life. Messages in the SS category will have in addition, in the origin section of the message following the originator, a priority alarm signal. This signal will consist of the FIGURES shift, five J characters, five S characters, and the LETTERS shift. When this alarm signal is sensed at the equipment in the switching center, visual and audible alarms will be activated to alert an attendant to the importance of the message and to insure minimum delay in switching.

Message Numbering

FAA requirements specified that a message transmitted to the line from the transmitter-distributor in a line sending position contain but one number. Message switching procedure used in previous switching systems results in two numbers appearing at the start of the message, the first inserted by the automatic message numbering machine in the line sending position, and the second transmitted cross-office from the sequence number indicator (SNI) in the receiving position. Although the problem could have been solved by blinding cross-office transmission from the SNI, this would have hampered message servicing by eliminating from the message tape in the sending position any reference to the receiving position at which the message had been received at the center. Consequently, it was decided to blind the outgoing sending line during the time the section of the tape containing the SNI number was passing over the pins of the line transmitter.

Routing Indicator Categories

Address routing indicators for which the switching center equipment is programmed are considered "valid." All others are "invalid." When invalid routing indicators appear in the address section of the receiving position tape, a code failure alarm condition will be initiated and the switching operation will be halted pending the action of an attendant. Invalid routing indicators will not be switched to the supervisor receiving position automatically.

Valid routing indicators will fall in either "action" or "no-action" categories. Action routing indicators represent destinations to which the center is responsible for routing the message. No-action routing indicators represent destinations for which the message originator or an earlier relay point takes routing responsibility and which this switching center will ignore. It should be emphasized that whether a routing indicator will be action or no action is a function of the particular receiving position on which it is received at the center, the important determinant being whether routing responsibility has been normally assumed by the originator or by an earlier relay point.

SWITCHING CENTER EQUIPMENT

The switching aisle of a typical Plan 59 switching center (Figure 2) is equipped with five specialized types of operating position cabinets and one director-translator cabinet with associated center routing cabinet. Certain additional equipment

Photo R-11,993

Figure 2. Main switching aisle, FAA Plan 59 Switching Center, Honolulu

is required also to provide the auxiliary functions necessary for proper message servicing and equipment maintenance.

The electronic equipment used in pulse generation and control features solid-state circuitry, with thyratron readout used where electromechanical devices such as relays or reperforator selector magnets must be actuated. The electronic equipment is assembled on plug-in modules (Figure 3) which may be swapped out rapidly in the event of trouble to minimize circuit down time. The relay circuitry also has been packaged on easily removable chassis to provide similar ease in replacement. Such arrangements become mandatory in a switching center such as Honolulu which operates on a 24-hour-a-day schedule.

Input, output, and control circuits of the several cabinets housing the director and operating positions are terminated in multiterminal connectors to provide for rapid installation and minimize set-up time. Prefabricated "end panel modules," each consisting of a length of multiconductor cable terminated at one end in a multiterminal connector and at the other in a small taper-pin patching panel, are furnished to provide patching appearances for each position at the primary and secondary patching racks located in the end panels of each equipment row. This arrangement obviates the tedious and time-

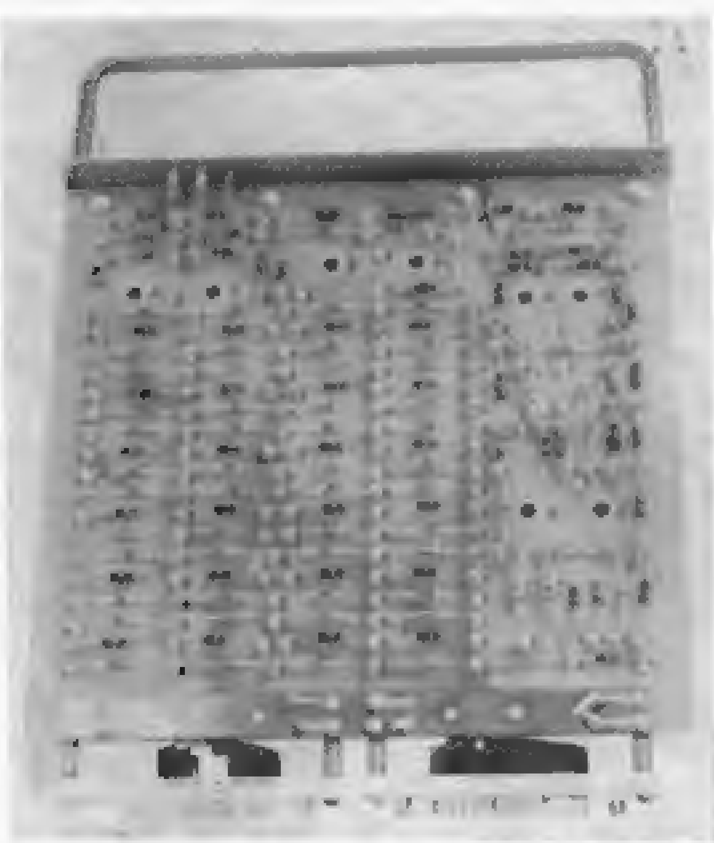

Photo R-11,324

Figure 3. Typical electronic equipment module

Chattanooga Photo

Figure 4. Line Send-Receive Cabinet 9938-A

consuming task of wiring these patch panels at the time of installation.

LINE SEND-RECEIVE CABINET 9938-A, Figure 4, houses one line receiving position on its upper shelf and one line sending position on the lower. It is used to terminate the receiving and sending legs of a single trunk circuit. Each cabinet provides for cross-office message switching on a fully automatic (director) basis or push-button (manual) switching to a maximum of 80 destinations. Messages requiring transmission to more than two destinations will normally be switched automatically to an MX (multiple address) position described below, from whence they will be retransmitted to the appropriate cross-office destinations.

WAY SEND-RECEIVE CABINET 9978-A, Figure 5, contains a way receiving position in the upper section and a way sending position in the lower and terminates the receiving and sending legs of a multipoint circuit. Each way send-receive cabinet can send to and receive from any one of 18 way stations on a full duplex basis, and will provide for fully automatic cross-office switching to a maximum of 80 destinations. For messages addressed to more than two destinations, the MX cabinet will be employed. The push-button panel for manual cross-office routing used in the line receiving position is not required in the way receiving position, since it is capable of switching to all destinations, and QSP handling will not be required. In addition, the way circuit line facilities in general will not include long-distance radio circuits, so the problem of garbled message reception will be infrequent. However, the way position is arranged to switch any messages that are received with a garbled address section to the supervisor position on an automatic basis. Switches on the way send-receive cabinet permit any combination of the 18 outstations to be closed out, with any traffic intended for them being diverted to a way intercept or a way spillover position discussed below, depending upon whether the way station is to be closed out for a short time or for an extended period.

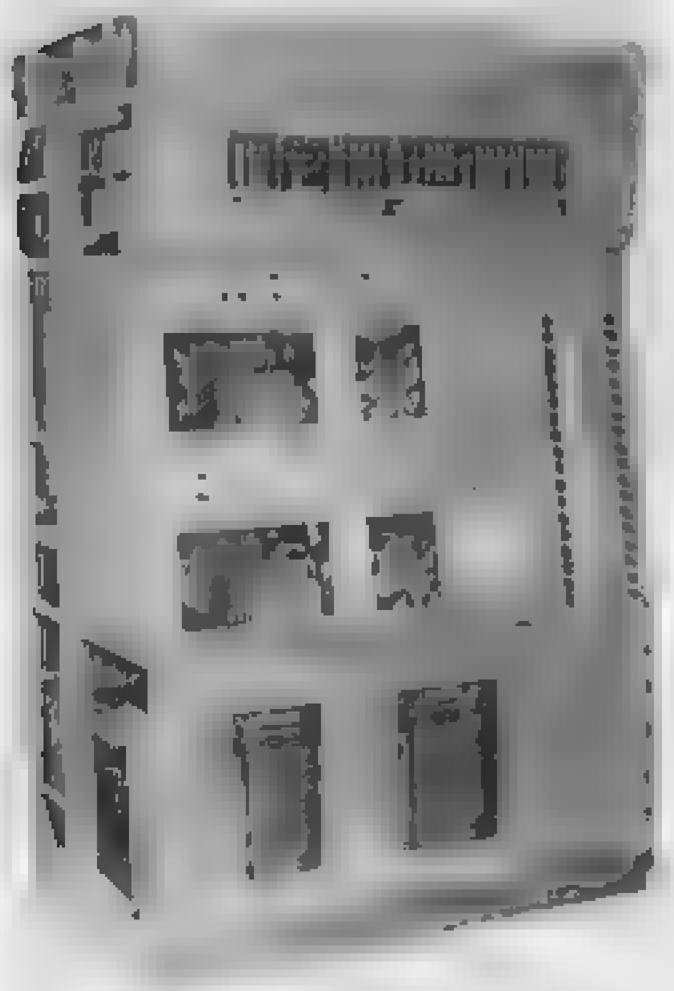

Figure 5. Way Send-Receive Cabinet 9978-A

SUPERVISOR'S CABINET 9942-A, Figure 6, is provided to process messages requiring special handling. The supervisor position does not terminate an incoming or outgoing line, but functions entirely within the intraoffice circuit. A sending position located in the lower portion of the cabinet receives messages directed to it from line or way receiving positions at the 200-wpm cross-office speed. Messages from line receiving positions are transmitted to the supervisor position automatically by director switching, or manually in response to push-button switching by an attendant at the line position. Messages from way receiving positions are transmitted to supervisor automatically should the way position detect an error in the heading or address section of the received tape. Messages are transmitted from the supervisor sending position at 100-wpm speed either to the supervisor receiving position in the upper portion of the same cabinet, for further processing, or to a file printer located in the data processing section of the switching center for ultimate action

Messages received at the supervisor receiving position from the supervisor sending position are transmitted cross-office to selected line and way sending positions at 200 wpm. Up to 80 destinations served by a maximum of 40 sending positions can

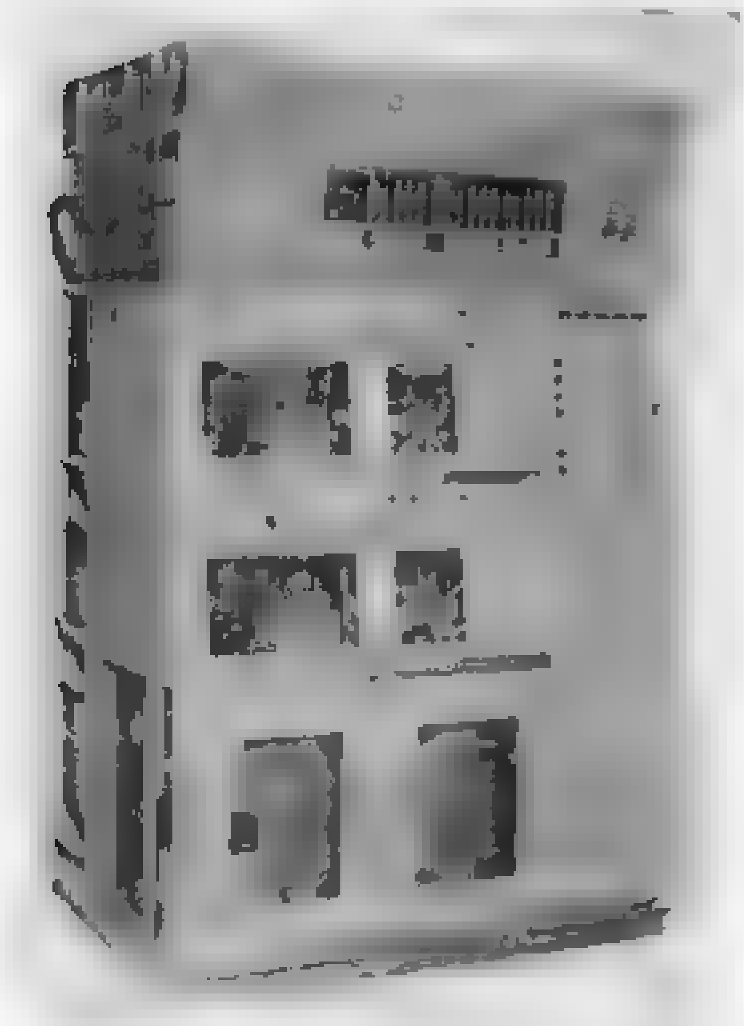

Figure 6. Supervisor's Cabinet 9942-A

be selected on an automatic (director) or push-button (manual) basis.

MX (MULTIPLE ADDRESS) CABINET 9944-A, Figure 7, provides facilities for handling messages addressed to three or more destinations. The MX position functions entirely within the cross-office 200-wpm circuit. When such multiple-address messages are detected at a line or way receiving position they are switched cross-office automatically to the upper position in the MX cabinet for processing. A bank of 80 neon lamps located on the right-hand side of the cabinet contains one lamp for each possible destination. These lamps provide an indication as to the cross-office destinations that have been requested, and those to which connections have been obtained. The lower position in the MX cabinet acts as a "spillover" to accept the message for those sending positions to which connection cannot be achieved within a predetermined time period and to process it subsequently until all destinations have been reached.

Chattanooga Photo

Figure 7. Multiple Address (MX) Cabinet 9944-A

WAY INTERCEPT CABINET 9980-A, Figure 8, is used with Way Send-Receive Cabinet 9978-A to provide a temporary destination for messages addressed to closed-out way stations. The way intercept cabinet contains an upper and a lower operating position, known as the way intercept and way spillover positions, respectively. Messages diverted from a closed-out way station at a way send-receive cabinet will be sent to the way intercept position if the close-out period is expected to be of short duration, and to the way spillover position if a long shutdown is anticipated. Messages transmitted to the way intercept and spillover positions will be sent from the way send-receive cabinet at the regular outgoing line speed as though they were being

transmitted to an outstation. From either position, the messages will be sent cross-office automatically to the way sending position for transmission to the way station when the close-out condition has been removed

Chattanooga Photo

Figure 8. Way Intercept Cabinet 9950-A

DIRECTOR-TRANSLATOR CABINET 9940-A, Figure 9, houses the circuitry to furnish routing information for any of 525 single-address and 25 group-code routing indicators, when requested by a connected receiving position. The director can also furnish switching codes for up to 30 special way position and 18 way station routing indicators employed by the way intercept and way spillover positions in achieving cross-office connections to way sending positions, as discussed below. Located in the director are four Code Reading Card Assemblies 9743 with facilities for mounting up to 600 address coding cards. The director will contain an address coding card for each valid routing indicator which may appear in the address section of an incoming message, a maximum of 598. The remaining two address coding cards

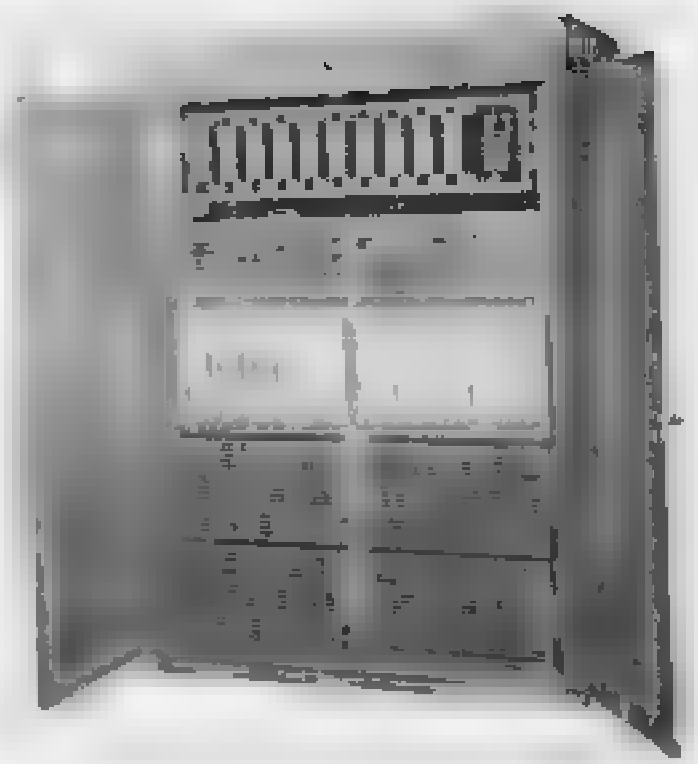

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Figure 9. Director-Translator Cabinet 9940-A

are coded to read the end-of-routing sequences used by the line and way positions (< ≡) and by the way intercept and way spillover positions (—Z)

CENTER ROUTING CABINET 10146-A, Figure 10, is used in conjunction with the

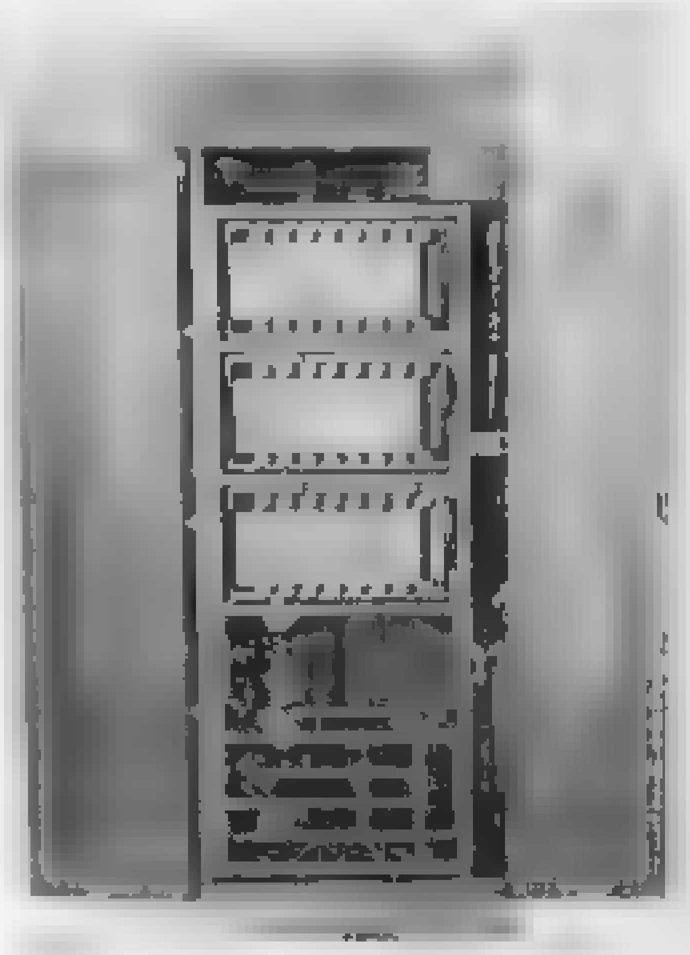

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Figure 10. Center Routing Cabinet 10146-A (rear)

director-translator to provide an assigned pattern of address routing indicator action and no-action treatment for each line receiving position in the switching center, depending upon the positioning of the five toggle switches in Line Send-Receive Cabinet 9938-A. The pattern will determine which of the routing indicators appearing in the address section of the message at the receiving position will have a switching code furnished, and which will be no-coded

Dual Sending Control Cabinet 10085-A, Figure 11, provides means for introducing messages into the Plan 59 system. Mounting two transmitter-distributors which may be used singly or on an alternate or flip-flop basis, and an automatic message numbering machine, the dual sending control cabinet transmits at line speed into the receiving position of a Line Send-Receive Cabinet 9938-A in the switching aisle.

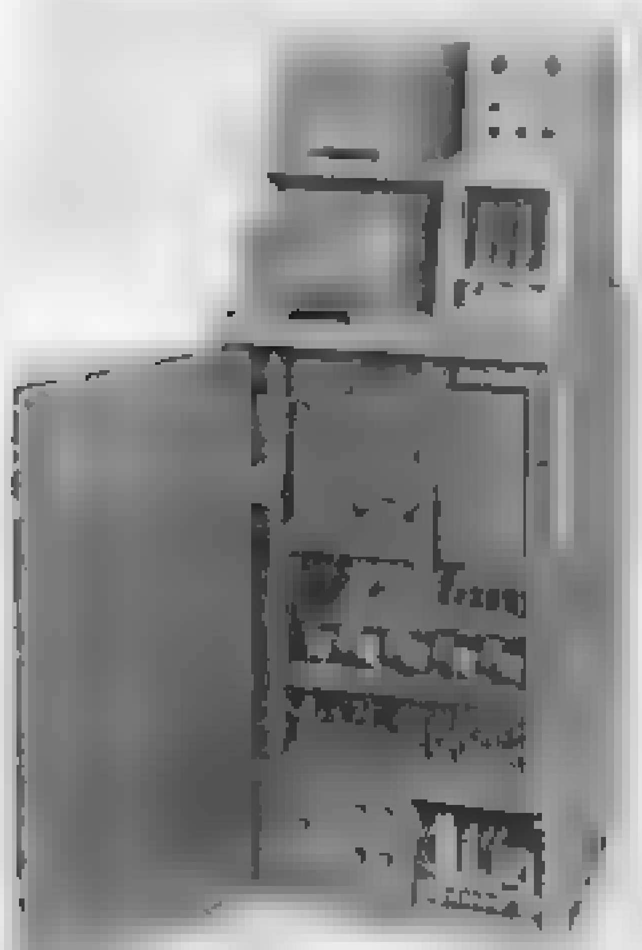


Figure 11 Dual Sending Control Cabinet 10085-A

Portable Local Terminal Table 9986-A is provided to expedite servicing "reruns" where tape previously transmitted to the line from a line sending position must be retransmitted. The table mounts a transmitter-distributor and a typing reperforator with keyboard, plus a tape winder for rapidly scanning reeled tape, and tape editing facilities

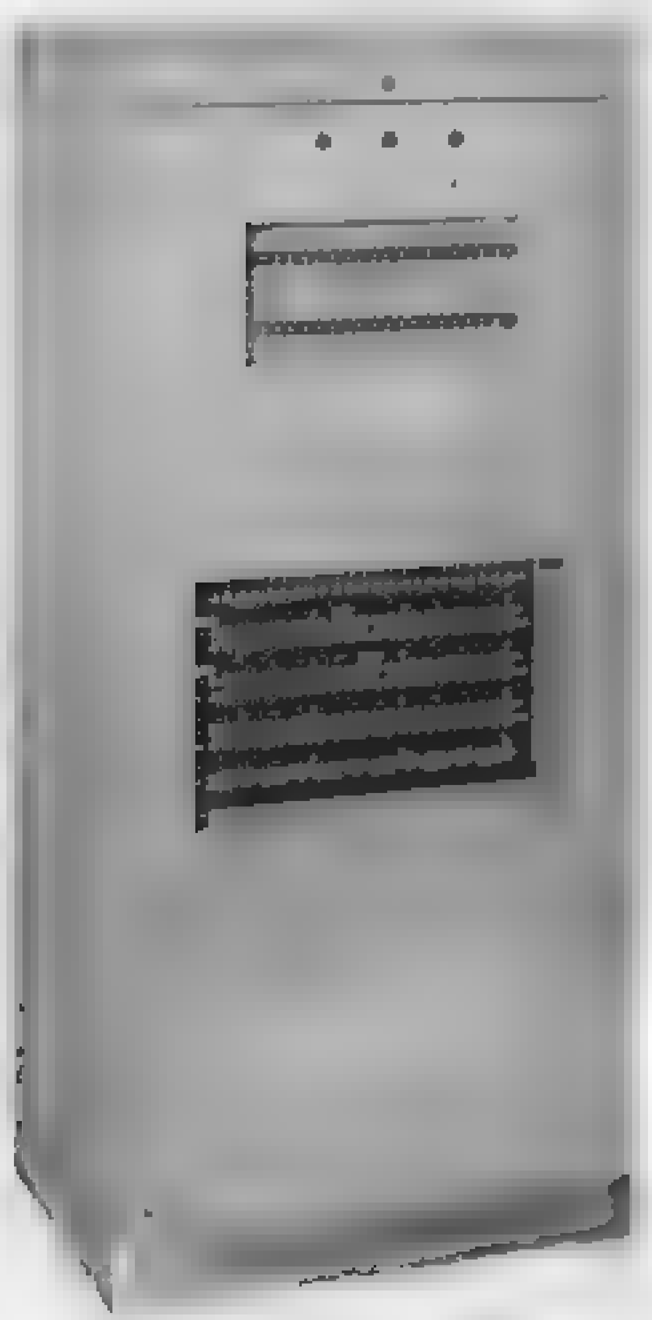
Meteorological Equipment Cabinet 9990-A, Figure 12, contains facilities for monitoring selected incoming trunk lines to determine if incoming messages on those trunks contain the specified start-of-message (SOM) and end-of-message (EOM) sequences. Messages not in this format are assumed to be meteorological messages, and are diverted to special meteorological positions not associated with the Plan 59 center. Messages in proper format are diverted in normal fashion to the line receiving position

Figure 12. Meteorological Equipment Cabinet 9990-A

Traffic Routing Board 9984-A, Figure 13, permits the outgoing line transmitters in line or way sending positions to be stopped and started remotely, either singly

or in groups. It also provides a jackboard for sending position route lead appearances to allow normal route lead assignments to be changed for alternate routing of cross-office traffic.

TEST TABLE 9982-A provides means for maintenance testing the mechanical apparatus and electronic modules used in the various switching center equipment cabinets. The test circuits on the test table simulate the actual operating circuits at the operating positions, and employ a complete set of mechanical and electronic equipment kept in working condition for exclusive use on the test table. Defective equipment removed from an operating position can be substituted for the working equipment on the test table. Switches and test lamps allow individual circuits to be operated and their responses checked individually, so that a fault may be localized and corrected quickly.



Chattanooga Photo

Figure 13. Traffic Routing Board 9984-A

Power Supplies

The several voltage levels required for operation of a Plan 59 switching center are provided by rectifiers located in the d-c distribution bay. Regular and fallback direct current at the +120-volt level is furnished by a bank of SK45-120 silicon rectifiers rated at 45 amperes each. Rectifier Patching Cabinet 9812 allows up to six of these rectifiers to be connected to load busses on a regular or spare basis.

Transistor voltages of +5 and −20 volts are supplied from precisely regulated and adjustable power supplies mounted in D. C. Power Supply Cabinet 9814. Switches are provided so that a fallback rectifier may be substituted for any of the regular units in the event of a rectifier malfunction.

D. C. POWER DISTRIBUTION CABINET 9816 contains the regular and fallback rectifiers which furnish ±150 volts to the vacuum tube circuits of Director-Translator Cabinet 9940-A, as well as the regular and fallback phasing transformer which furnishes 30 volts, 60 cycles alternating current used for the timing and control of cross-office transmissions.

Figure 14 illustrates the layout of a typical Plan 59 switching center. The operating cabinets shown arranged in two rows are closed off at the ends with end panels which house the primary and secondary patching racks, together with certain miscellaneous equipment. Each of the two patching racks is composed of a series of permanently mounted taper pin panels (PPN) which terminate such conductor groups as sending position route lead and cross-office line conductors, and incoming and outgoing lines. Adjacent to these permanently mounted panels are framed openings in which the pin panels associated with the individual operating position cabinets may be inserted and mounted. These removable pin panels are wired to a length of cable which is terminated in

a multipin connector for insertion in the mating connector at the operating position. The complete assembly of taper pin panel, cable, and connector is known as an "end panel module." Operating positions are connected into the system with color-coded patch cords between selected pins on end panel module pin panels and permanently mounted pin panels. This arrangement provides an easy and effective method of equipment interconnection which may be quickly and efficiently checked.

The Model 28 RO printer at a particular outstation will copy all messages directed to that drop. Through its stunt box it will be controlled by the selection and certain other characters transmitted from the way sending position in the switching center

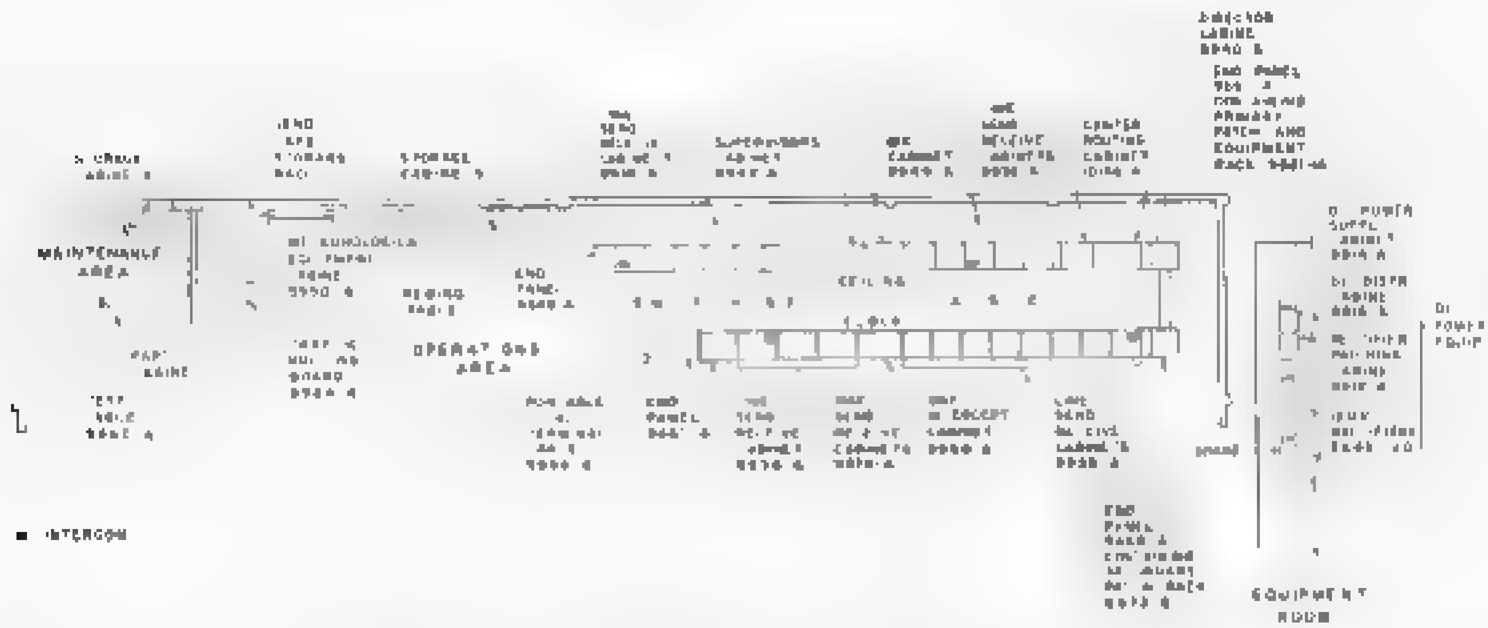


Figure 14. Typical Plan 59 Switching Center equipment layout

OUTSTATION EQUIPMENT

Each way circuit terminating in a Way Send-Receive Cabinet 9978-A may have up to 18 outstations or drops associated with it. In general the equipment at each outstation will consist of a Model 28 automatic send-receive (ASR) set for sending, and a Model 28 receiving-only (RO) printer with "stunt box"[4] for receiving, plus Duplex Way Selector 9782-A. The outstation will send and receive at 75 wpm on a full duplex basis.

The Model 28 ASR set utilizes a keyboard for the manual preparation of perforated message tape, a tape transmitter for transmitting the tape information to the way circuit, and a page printer which may be employed on an optional basis to copy transmissions to the way circuit, or to provide home copy during tape perforation.

Circumstances sometimes dictate variations in the outstation operating mode. Way station selectors are available which will permit receiving-only operation with printer or typing reperforator, and sending-only operation with an ASR set. The latter may be installed either by itself or as an auxiliary sending position at an outstation equipped for full duplex operation.

SWITCHING SYSTEM OPERATION

Line Send-Receive Cabinet

Message traffic entering a Plan 59 switching center may be handled in a variety of ways, depending upon such factors as the number of routing indicators in the address section or whether it was received over a trunk or multipoint circuit.

Figure 15(1) illustrates a typical message received over a trunk circuit and copied on a Model 28 typing reperforator, Type LPR-11, in the receiving position of a Line Send-Receive Cabinet 9938-A. Electronic circuits operated in conjunction with the reperforator tape sensing contacts will read the start-of-message (ZCZC) and

end-of-message (LF NNNN) sequences to control operation of a message waiting indicator. This device will indicate the number of messages awaiting cross-office switching action, as well as control the tape metering function. It also will prevent a cross-office connection from being established under certain conditions described below

The printed and perforated message tape will be pulled by a tape crimper[5] down a tape chute and back up over the sensing pins of a loop-gate transmitter.[5] This transmitter will operate continuously at a 200-wpm stepping rate, but will stop automatically (auto-stop) under certain alarm conditions and during the switching process, or when a tight-tape condition activates a lever arm associated with the tape crimper

As the tape passes over the sensing pins of the tape transmitter, the characters of the channel number will be checked by electronic circuits in a sequence number indicator (SNI), to make certain that the message is following in proper sequence Should the channel number fail to check properly, a "wrong comparison" alarm will stop the tape transmitter and a visual indicator will alert an attendant

A switch is available for bypassing the SNI comparison feature when it is recognized that messages entering the position will purposely not be in sequence. Such a case would occur if more than one remote position, each using its own number series, were sending into this receiving position on a load distributed basis. In this case, with the SNI comparison feature bypassed, the wrong comparison alarm circuit will be disabled. The SNI, however, will continue to step through those points where number comparison normally would take place, coming to rest on the point from which cross-office transmission will commence, as discussed below

Assuming that the channel number group compares correctly, the tape will continue to step through the tape transmitter while the sequence number indi-

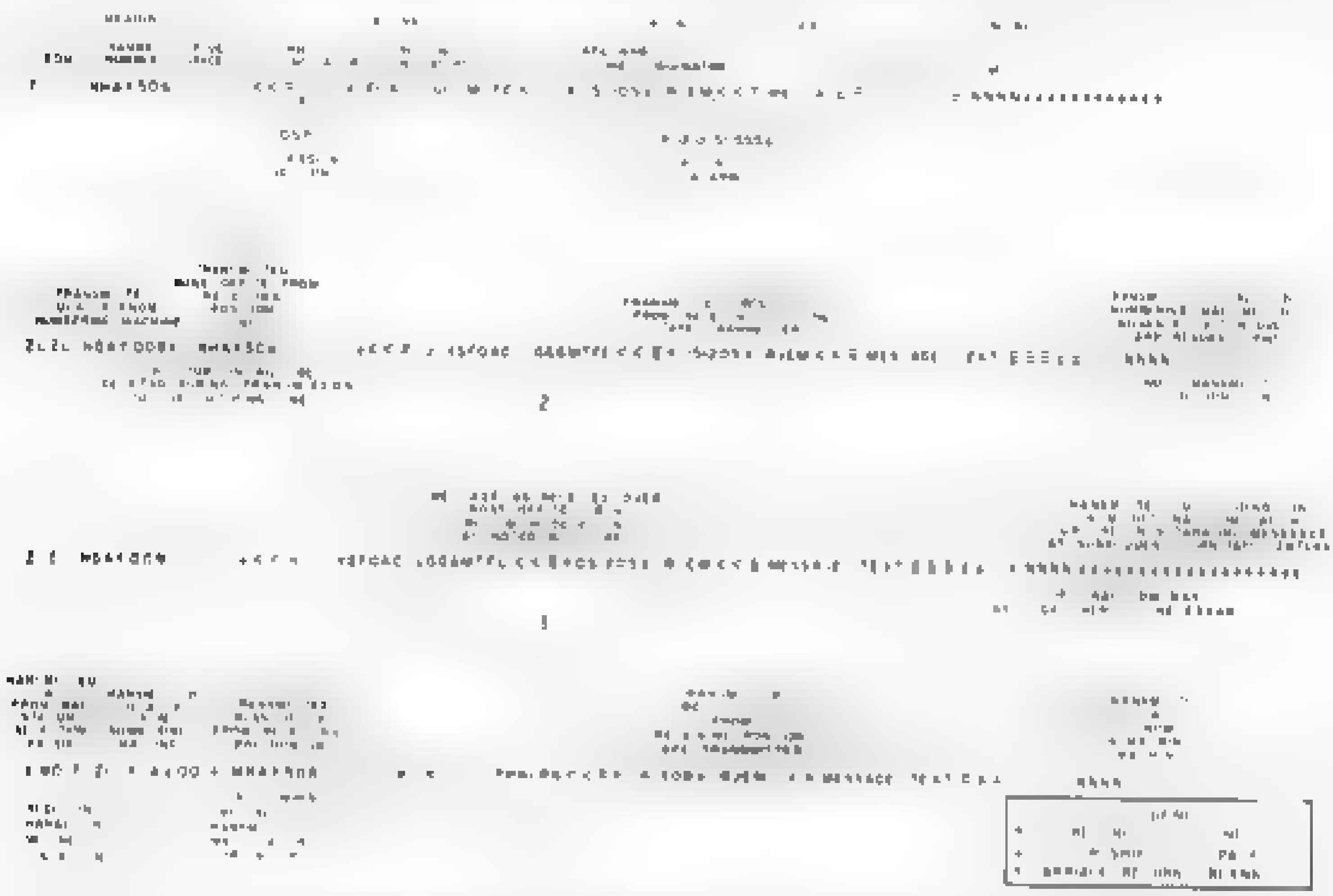


Figure 15. (1) Typical message as received on typing reperforator in line receiving position; (2) Typical message as received over cross-office circuit at line sending position; (3) Typical message as transmitted to outgoing line from sending position in line send-receive cabinet; (4) Typical message as received over cross-office circuit at sending position in way send-receive cabinet

cator reads for the first SPACE function following the message number. Upon sensing this space, electronic circuits activated by the sensing pin contacts of Tape Transmitter 7595-B will cause the transmitter to auto-stop and will shift the sliding tape gate from the normal right-hand position to the left-hand position, at which point the transmitter will resume stepping. From this point, the tape will no longer be stepped completely through the transmitter, but instead will form a storage loop after being stepped over the sensing pins. In this way, the information in the looped portion of the tape can be used to establish the cross-office circuit, and then be stored in the loop to be transmitted cross-office with the message later when the tape gate is returned to the right.

As the tape is stepped through the transmitter and the loop is formed, electronic circuits in the SNI will be activated to read for the 2-letter priority indicator and the SPACE function immediately following. When this sequence is sensed, the tape transmitter will again be auto-stopped and this receiving position will request connection to the director for processing the address routing indicator (s) which follow in the address section of the message tape

Should the message contain the diversion section (QSP-) discussed earlier, it will appear in the message tape directly ahead of the priority indicator. Consequently when the diversion section is sensed instead of the expected priority indicator sequence, the transmitter will auto-stop and a QSP alarm will be activated to alert an attendant to the fact that special handling for this message is required

Subsequent inspection of the tape by the attendant will disclose the routing indicators in the address line. The receiving position may then be placed in the "manual" mode and connection made to the sending position (s) involved by way of the manual push-button panel, without reference to the director

Assuming no diversion section, however, the request for the director will be followed by connection to the director; the tape transmitter will resume stepping, and the first routing indicator will be transmitted into the director

The director is an automatic computer device which contains electronic and relay circuitry to store and read the characters in a routing indicator, and to return the requested switching information to the receiving position. For each routing indicator which might appear normally in the address section of any message switched through the switching center, the director will contain an address coding card. Routing indicators for which the director does not contain an address coding card are considered "invalid" and will initiate a "code failure" condition to disconnect the director and activate a visual alarm, when read at the receiving position.

Assuming that the director does contain an address coding card for the routing indicator transmitted to it, this routing indicator may be treated further as either action or no action. As the terms imply, a switching code will be furnished to the connected receiving position for an action routing indicator, while a no-action routing indicator will be ignored. An exception occurs when the message contains but one routing indicator and it falls in the no-action category. In this one instance, the no-action indicator will result in a code failure alarm. Decision as to action or no-action treatment for a particular routing indicator is made on the basis of traffic studies as was explained earlier, and is programmed in the receiving position by means of five switches which may be set for any one of 32 mark-space combinations. At the instant the position is connected to the director, the "center routing" information represented by the particular mark-space combination of the five switches will be sent into the director to operate one of 32 multicontact relays in the center routing cabinet. Operation of this relay will activate a set of patch cords representing a unique pattern of action and no-action treatment for each of the 525 normal single-address and 25 group-code routing indicators for which the director may contain an address coding card

Assuming that the routing indicator sent to the director is one requiring action, the

director will furnish to the receiving position two grounds, one appearing at the position over one of 20 possible conductors, and the other appearing over one of four possible conductors. This arrangement permits 80 possible combinations of grounded conductors (switching codes), representing the 80 possible destinations to which traffic can be switched The two grounded conductors will position rotary switches in the line receiving position to a particular stud combination to allow connection to be made to the "route lead," a conductor running to that sending position designated to receive message traffic containing this particular routing indicator in the address section

The tape transmitter in the receiving position will auto-stop on the following SPACE function after the first routing indicator has been transmitted to the director, and will remain stopped while the director examines it and returns the switching code to position the rotary switches. At the conclusion of this function, the receiving position will transmit a code release to the director to release the storage circuits in the director and the tape transmitter will restart, to send the next routing indicator into the director The director will then return a switching code for this second routing indicator.

Since the receiving position contains but two sets of route lead rotary switches, it can handle but two switching codes each representing a single destination. As often happens, two or more routing indicators may represent the same cross-office destination, in which case the route lead selected for the first of these will be the same as for the second. In brief, the message being processed may contain any number of routing indicators in the address section, and providing they represent no more than two cross-office destinations, processing will proceed as outlined above. Should the receiving position transmit to the director a routing indicator requiring a third destination, however, previous route lead storage will be "dumped" and the receiving position will be connected to the MX (multiple-address) position route lead, to which position the message will subsequently be transmitted for ultimate distribution cross-office to the required sending positions

When the director has returned a switching code to the line receiving position for each routing indicator in the address section of the message, the end-of-routing sequence following the last routing indicator (<   ) will be transmitted to the director to initiate disconnection of the receiving position. At the conclusion of the disconnection process, the tape gate of the transmitter will be returned to its normal or right-hand position

Once disconnected from the director, the line receiving position will check the polarity of the voltage appearing on the route lead (s) to the desired sending position (s) which the route rotary switches have selected, to determine whether these sending positions are busy, idle, or closed It should be noted here that this route lead check cannot be made, and the allotter will not be seized, as described below, if the message waiting indicator pointer is at zero — an indication that there are no messages awaiting cross-office switching Cam contacts associated with the pointer shaft will disable the check circuit. Such a condition can occur, even with a legitimate message awaiting switching action, if the MWI is improperly set initially or if the message in the transmitter is lacking an SOM or EOM sequence Failure on the part of the electronic circuits associated with the reperforator tape sensing contacts to read an SOM or EOM sequence will disable the "add" function of the MWI. Subsequent switched messages will continue to cause the MWI to subtract, with the result that when the pointer reaches zero the offending message will be in the tape transmitter, unsuccessfully requesting switching action. Tape discrepancies may be corrected at this time by an attendant.

Assuming the idle condition obtains, a further check will be made through an allotter to determine that none of the other receiving position groups, and further that no other position in this particular group, is attempting to achieve a cross-office connection to a sending position at this instant. Should such prove to be the case, the allotter will be "seized" by the

receiving position, preventing any other receiving position from achieving a cross-office connection to a sending position until the allotter is released. After the allotter is seized, the route lead to the sending position will be seized. When the sending position recognizes this seizure condition, it will return information to the receiving position over certain "code group" conductors which will position the cross-office line rotary switches in the receiving position to the cross-office line connected to this sending position.

At this point a check will be made to determine that no other receiving position is connected to this cross-office line, at which point the line will be seized, the allotter will be released, and cross-office transmission from the receiving position to the sending position will commence.

Because of the unique function of the allotter in preventing the further establishment of cross-office connections until the receiving position that has seized it completes its connections and releases it, it is important that it not be held by the receiving position any longer than necessary to seize the cross-office line to the desired sending position. Should the receiving position fail to complete a line connection and release the allotter within approximately three seconds, a "route alarm" will be activated to release the allotter pre-emptorily, and alert an attendant at the receiving position to the fact that trouble has been encountered.

At the sending position, a Model 28 reperforator, Type LARP-5, will copy the cross-office traffic. Before transmission from the receiving position can commence, however, information will be transmitted to the LARP locally, from the automatic message numbering machine in the sending position. The numbering machine will cause to be punched into the LARP message tape a start-of-message sequence followed by a circuit identifier and message number, as shown in Figure 15 (2)

At the conclusion of the numbering machine function, the receiving position will be notified to commence sending. The first information transmitted cross-office from the receiving position will be from the sequence number indicator and will consist of the message number it had checked previously, just prior to operation of the transmitter tape gate to the left, and which had remained stored in the SNI, waiting to be transmitted after a cross-office connection was obtained

When the SNI concludes its sending, the tape transmitter will be restarted and will transmit the information which had been stored in the tape loop, followed by the message text and the EOM sequence. When the EOM sequence is read at the receiving position, a disconnection process will be initiated and the sending position will be released. The MWI also will subtract one from its total. The automatic message numbering machine in the sending position will insert five blanks in the LARP tape following the EOM sequence in order to step the last N character past the read-back pins of the LARP.

A continuous character-by-character check is maintained on the accuracy of both local and cross-office information punched into the message tape at the LARP reperforator in the sending position. This is accomplished by a system of even pulse parity whereby each character represented by an odd number of marking pulses will have an additional, or parity, pulse added to it. As a result, all characters transmitted into the sending position will be represented by an even number of marking pulses. The parity pulse information (presence or absence) will be stored in electronic circuits in the sending position. Read-back sensing pins in the LARP, probing each character immediately following the punching operation, will compare the character's odd or even marking pulse status with the stored parity information. Should an "odd" character have no parity pulse stored, or an "even" character have one stored, a "parity alarm" condition will be initiated which will blind the cross-office line to that sending position to further transmissions, as well as alert an attendant to the trouble condition.

The perforated tape from the LARP will proceed through a tape crimper,[8] tape chute, and tape accumulator to the tape transmitter sending to the outgoing line. This tape transmitter is the same type as

that employed in cross-office transmission from the receiving position, except that it operates at one of the conventional line speeds (100, 75, 67.5, 60 wpm) rather than the 200-wpm speed employed for cross-office transmission. A distributor is used in conjunction with this tape transmitter to furnish the proper stepping rate and to provide for sequential distribution to the outgoing line of the character pulses.

Each line sending position contains a rotary switch and associated circuitry which serves to delete transmission of the SNI number to the line. This switch acts to blind the outgoing line during the time the tape transmitter is sensing the sequence starting with the LETTERS shift following the last digit of the numbering machine number and ending with the last digit of the SNI number, as shown in Figures 15(2) and 15(3). Electronic circuits in the line sending position serve also to delete from transmission to the line the five blanks following the EOM sequence.

Provision is made also for an optional end-of-message switch which may be programmed to transmit any desired end-of-message sequence to the outgoing line, following the standard Plan 59 EOM (L F NNNN). Whether or not the optional EOM feature is used, the switch can be employed also to transmit up to 12 letters shifts following the EOM as an aid in separating messages at subsequent torn-tape switching centers.

MX Cabinet

As was pointed out previously, a receiving position can switch a multiple address message automatically to a maximum of 2 destinations. When a routing indicator requiring a third destination is sent into the director, any previous switching code information relating to routing indicators processed previously in the address section will be cleared out of the receiving position, and the receiving position will be connected to the MX position route lead. Subsequent route lead checking and cross-office line connection will be similar to that previously described for connection to the destination line sending positions.

Cross-office line connection is made to the upper, or sending position, in the MX console. The first information transmitted from the connected receiving position will be that programmed on the five center routing switches in the receiving position. This information will be punched into the message tape by the MX position LARP reperforator ahead of the MX position local number from its numbering machine. This information is required so that when the MX position makes connection to the director, it will provide the same pattern of "action" and "no action" for the address routing indicators as though the director were connected to the original receiving position. Subsequent LARP operation will be similar to that previously described for the line sending position.

The message tape from the LARP will be stepped through the MX sending position tape transmitter at a 200-wpm rate. When connection is made to the director, it will return a switching code for each destination required up to the 80 maximum of the switching center. As the routing indicators are processed through the director, a lamp in an 80-lamp bank on the front of the console will light for each destination requested. As cross-office line connection is made to each of the line and way sending positions representing these destinations, its associated lamp in the bank will be extinguished. When all lamps have been extinguished, the MX position will proceed to transmit the message to the connected line and way sending positions.

If one or more of the desired sending positions is busy and cross-office connection cannot be established within a predetermined adjustable time period, the lamps representing these destinations will remain lit and the routing information will remain stored in the MX receiving position. The upper position will proceed to transmit the message to whichever positions have been connected, and to the lower MX position as well. From this point the lower MX position will process the message in a manner similar to what the upper position has done, using the stored routing information, until the message has

been sent to all destinations and all lamps have been extinguished.

Supervisor Cabinet

The lower or sending position in the supervisor cabinet receives messages directed to it in the manner previously described for the line sending position, at 200 wpm over the cross-office circuit, on a LARP reperforator. Messages from line receiving positions are switched to the supervisor sending position in response to manual switching by an attendant using the manual push-button panel on the line send-receive console. Messages can also be switched cross-office to the supervisor sending position from either line or way positions on an automatic basis if they contain the supervisor routing indicator (SUPVA), and the director contains an address coding card for this address. Messages received at a way receiving position and containing a garbled routing line also will be switched automatically to the supervisor sending position for handling.

The supervisor sending position will transmit at 100 wpm either to the supervisor receiving position in the upper section of the same console, or to a file printer located in the data processing section at the switching center. Messages transmitted to the supervisor receiving position will be received on a Model 28 typing reperforator, Type LPR-11, the tape from which will be stepped through a 200-wpm tape transmitter in a manner similar to that in the line receiving position previously described. The supervisor receiving position can process through the director in automatic fashion, but since the majority of messages are those which could not process automatically at the original receiving positions, a push-button panel containing 80 buttons located on the front of the console allows messages to be inspected and then switched on a manual basis by an attendant to the maximum of 80 destinations.

Way Send-Receive Cabinet

Operation of the way position can best be understood if the cross-office switching operation is handled separately from multipoint operation. The way send-receive cabinet functions on the cross-office side in much the same fashion as the line send-receive cabinet and since operation of that position was covered in considerable detail, it will not be repeated here. However, it would be well to point out certain features in which the way cabinet differs to some extent from the line cabinet.

The way receiving position does not employ the manual cross-office switching option — all traffic which cannot be switched cross-office to the destination(s) represented by the address routing indicator(s) will be switched automatically to the supervisor position. The reason for this difference is the absence of QSP traffic on the multipoint circuit, for the handling of which messages the manual switching feature was provided in the line cabinet. The diversion section (QSP-) dealt with earlier indicates that the message contains address routing indicators not routed normally through this switching center. The way receiving position does not employ the five switches which determine the center routing pattern by which address routing indicators appearing in its received messages are determined to be action or no action. The way position must treat all routing indicators on an action basis since it can be assumed that each of the drops on its multipoint circuit have but this one outlet for message traffic.

In contrast to the line sending position which represents but one cross-office destination and has one route lead, the way sending position can represent up to 18 destinations and consequently must employ up to 18 route leads when fully equipped. When a route lead to a way sending position is seized by a receiving position and the cross-office circuit between the two is established, the first information punched in the tape of the LARP reperforator will be, not the local number as in the case of the line sending position, but a way station selection character representing the destination (drop) called for by the routing indicator. The selection character will be transmitted

from a way station selection chassis in the way sending position. A selection character will be punched in the LARP tape for each of the 18 route leads seized by the connected receiving position. The selection character (s) will appear in the tape preceded by a LETTERS function and the character W, and followed by a space function as shown in Figure 15 (4) When the connected receiving position is a line receiving position, it can seize no more than two route leads. However, either the supervisor or the MX position is capable of seizing all 18 route leads of the way sending position should the switched message contain more than two routing indicators

After the selection characters have been punched in the LARP tape, operation proceeds as in the line sending position, with the numbering machine local number inserted next. Transmission will continue from the connected receiving position SNI and tape transmitter, through the disconnect process when the EOM sequence is read.

Multipoint Operation

TRANSMITTING TO THE WAY STATION. As tape from the LARP in the way sending position, Figure 15 (4), advances through the tape transmitter, electronic circuits will read for the first nonblank in the tape, allowing preceding blank characters to idle through at a 200-wpm stepping rate. Upon sensing the first nonblank, in this case the LETTERS function, electronic circuits will be activated to remove the "blank idle" stepping arrangement and restore normal transmitter stepping at specified outgoing line speed through the sending distributor.

The transmitter will now advance the tape to the W character which will be read to unblind the line sending relay in the way position. The tape transmitter stepping circuit will be disabled so that the W will remain over the sensing pins to be transmitted a second time. On this second occasion the W will be transmitted over the sending leg to all way stations on the multipoint circuit. Should any of the way stations be in the process of sending a message to the center, the W will serve to suspend such operation temporarily so that the receiving leg may be used in the selection process.

The tape transmitter will now step the selection character, D in this instance, over the reading pins and transmit it over the sending leg to the way stations. In conjunction with the stunt box in the Model 28 RO printer and the selector at the outstation, this character will serve to shift the RO printer at the corresponding outstation from nonprint to print case. The transmission of the D will also activate relay circuits in the way sending position which will result in the generation and transmission of a LINE FEED function to the outstation following the D character. Since the RO printer at the outstation is now in print case it should respond to the LINE FEED function by feeding paper, which action will activate certain relay circuits in the selector

The tape transmitter meanwhile has been prevented from stepping so that the D character will again be sent to the line following the LINE FEED. The D character will now be printed on the RO printer of the selected outstation, and the outstation will answer back by transmitting to the center the complement of the selection character, in this case the character P

Should the outstation fail to respond to the LINE FEED as described above, the way station will return a BLANK rather than the proper answer-back character to the way sending position in the center The way position will interpret this as a trouble condition at the outstation and an alarm will be activated

After the correct answer-back has been received, the SPACE function will be stepped over the transmitter pins and sent out on the sending leg. Reception of the SPACE at the outstations will cause any outstation from which transmission had been interrupted for the selection process to resume sending. The tape transmitter will be prevented from stepping so that the SPACE may be transmitted a second time. The complete message will be transmitted to the outstation following the second SPACE.

Electronic circuits have now been alerted to read for the start-of-message sequence ZCZC—. When the SOM is read, a sequence number indicator similar to that described previously for the line receiving position will be activated to check the local message number. The SNI will intervening blanks at a 200-wpm rate until the next nonblank is read to start the selection process for the next message.

Receiving from the Way Station. A way station can transmit to its way receiving position in the switching center only when invited to do so by the way position.

Figure 16. (1) Message as prepared at a way station for transmission to a way receiving position at the switching center; (2) Message as received from way station at way receiving position in the switching center; (3) Message as received from way sending position at typing reperforator in way intercept position

check the three circuit identification characters, the FIGURES shift, and the three digits of the message number, at which point it will assume deletion functions, deleting from transmission to the line the following LETTERS shift, the SPACE function, the three cross-office SNI identification characters, the FIGURES shift, and the three digits of the number. Transmission to the outstation will resume with the SPACE following the cross-office SNI number.

The way sending position will be disconnected from the way station when the EOM sequence is read. When the first BLANK following the EOM is sensed, the sending line will be blinded to further transmission from the way sending position. The tape transmitter will return to the control of the "blank idle" stepping circuit which will step the tape through

Figure 16(1) shows a message as prepared in tape form on the keyboard perforator of the Model 28 ASR set at an outstation. The tape will be placed in the line transmitter and the blanks idled through until the first nonblank character, a SPACE function, is read. The attendant at the outstation will depress the request button to transmit a SPACE function and notify the switching center that there is a message awaiting transmission. When the way position at the center receives the request signal, it will interrupt its own transmission, if any, and will proceed to initiate an invitation cycle. During the invitation cycle each outstation is queried in turn as to whether or not it has traffic to send

The way position signals the start of the invitation cycle by transmitting the character Y to all outstations. The Y will prevent the outstations from initiating re-

quests during the invitation cycle. The invitation consists of successive transmission of the selection characters representing the drops on the multipoint circuit. Upon receiving its selection character, the outstation will respond with a SPACE function if it has no traffic waiting, and with a Y character if it has a message awaiting transmission. Should the response be a Y, the way receiving position line numbering machine will transmit a message number to its LPR-11 Typing Reperforator Numbering machine transmission will conclude with a CARRIAGE RETURN function, which will be sent over the sending leg to the outstation. The sending position will resume any transmission which had been interrupted for the invitation cycle. Upon receiving the CARRIAGE RETURN the way station will proceed to transmit its message as shown on Figure 16(2), while the completion of the selection process is postponed. Upon reading the EOM, the way position will again interrupt its own transmission, if any, and a rotary switch in the way receiving position will transmit a LINE FEED function to the outstation, causing the outstation number register to advance one count. The way receiving position will disconnect from the outstation and will resume the interrupted invitation cycling, continuing until a SPACE (no message response) is obtained from each outstation during one complete invitation cycle. At the conclusion of this cycle, inviting will cease and the way position will transmit a FIGURES shift to the outstations to permit outstation requests to be transmitted again.

The invitation cycle will be initiated automatically by the way position in the switching center should the receiving leg remain idle for an extended period. The invitation cycle can also be initiated manually at the way position if desired.

Way Intercept and Way Spillover Cabinet

A bank of 18 switches located on the right-hand side of the way send-receive cabinet (Figure 5) allows traffic addressed to closed-down way stations to be diverted to a way intercept or a way spillover position pending resumption of operation at the outstation. The way intercept position is designed to accept traffic from way sending positions during temporary outstation shutdowns and immediately to retransmit it cross-office automatically, back to the way sending position. The way spillover position, on the other hand, will accept messages for storage when the outstation is closed down for an extended period. The spillover position cross-office transmitter is normally held stopped except when an outstation resumes operation and it is desired to transmit stored traffic to it.

Assuming that the switch representing the D drop is thrown to the intercept position, the tape from the LARP in the way sending position will advance through the tape transmitter and the LETTERS function, Figure 15(4), will be read as the first nonblank. The loop-gate solenoid will be energized and the gate will shift to the left. The gate will shift when at least one of these 18 switches is set off its normal position to either intercept or spillover. The purpose of this is to allow the section of the tape containing the selection characters to be read twice; the first time in order to set up connections to a way sending line, or a way intercept or way spillover position. When the loop gate returns to the right, the selection characters will be read a second time for transmission to the connected sending line or positions. It should be pointed out that although the message shown in Figure 15(4) shows but one selection character following the W, D in this case, it is possible for a way circuit operating at full 18 drops' capacity to have as many as 18 selection characters between the W and the SPACE.

The W following the LETTERS shift will be stepped through the transmitter and stored in the tape. Next, the selection character D will be read and a request made for a way intercept position.

This request will be signified by the operation of a relay in the way sending position which will light an intercept request lamp there and actuate additional relay circuits in the way intercept position. A transmitter finder rotary switch located in the way intercept position, and

having 30 active stud levels representing the potential 30 way sending positions which may achieve a connection to this way intercept position, will rotate and stop at the stud representing the particular way sending position now requesting connection.

This action will actuate additional relay circuits in the way intercept position which will cause a numbering machine to commence stepping and to transmit a local number into the LPR-11 Typing Reperforator in the intercept position. As in the case of the line sending position described above, the local number will consist of channel identification characters, a FIGURES shift, and the three digits of the message number, as shown in Figure 16 (3).

At the conclusion of transmission of the intercept number, the numbering machine will proceed to transmit a 2-letter circuit identification group representing the way sending position that is requesting connection. This 2-letter group is a function of the stud level to which the transmitter finder switch had positioned itself, and is generated through a diode matrix capable of furnishing up to 30 such 2-letter circuit identification groups. When the 2-letter group has been sent, relay circuitry in the intercept position will function to close the line and answer-back circuits to the way sending position. Also, the intercept request lamp will be extinguished, the intercept connect lamp will be lit, and the sending line from the way sending position to the way intercept position will be unblinded. When the SPACE is read at the way sending position, the loop gate will be released to return to the right-hand position.

The character W, the first that had been stored in the loop, will now be transmitted to the way intercept position where it will be read to signify the start of the selection character group. The D will next be transmitted, after which the transmitter will be stopped so that this character will remain over the reading pins to be transmitted a second time on another operation of the sending distributor. Upon receiving the D a second time, the way intercept position will transmit the complementary character P to the way sending position. Comparison circuits in the sending position will compare the selection character with the "answer-back." A proper inverse condition allows the transmitter to step the D character out and bring the following SPACE function over the pins. The SPACE will release the selection circuit and allow message transmission from the way position to the intercept position to commence subject to correct comparison by the outgoing sequence number indicator.

Figure 16 (3) shows the message as received on the LPR-11 Typing Reperforator in the way intercept position just prior to its entering the tape transmitter for transmission cross-office to the way sending position. As was pointed out previously, intercept handling is intended for messages addressed to stations closed out for short periods, and such messages will continue to circulate through the intra-office circuit until operation is re-established at the outstation. Messages directed to the spillover position, on the other hand, will not recirculate unless specific action is taken at that position, since the extended shutdown of the drop would only cause them to return again to spillover, and so on ad infinitum. Except for this difference the operation of the intercept and the spillover positions is in general similar

As the tape from the reperforator advances through the loop-gate transmitter, message number comparison will take place in the sequence number indicator, at the completion of which a request for the director will be initiated by the following SPACE function.

When the connection to the director has been achieved, the first "short" intercept routing indicator—the characters AS in the example, Figure 16 (3)—will be transmitted into it and stored. The W character following the 2-letter group will be read at the intercept position to auto-stop the tape transmitter while the director inspects the routing indicator and returns a switching code corresponding to the desired way sending position, to the intercept position. The switching code will be stored in the intercept position in the form of an operated relay representing the

one-of-30 way sending positions represented by the 2-letter routing indicator (AS). The intercept position will thereupon transmit a "code-release" to the director, and its tape transmitter will restart, to send the next routing indicator (DD) to the director. The switching code returned for this routing indicator will be stored in the intercept position on a relay representing the one-of-18 way stations (DD) served by the way sending position selected by the first 2-letter group (AS). Additional 2-letter station codes, if any, will be handled in similar fashion. It should be noted that although the regular routing indicators (PHIK and PHNLYF) appear in the tape, they are not employed in cross-office switching from the way intercept position to the way sending positions. The way intercept or way spillover positions may also switch message traffic on a manual basis without reference to the director through the use of a push-button panel located on the console to the right of the intercept position.

After disconnecting from the director at the completion of routing indicator processing, an allotter request and connection will be made in the manner described previously for the line receiving position. The cross-office line to the way sending position will be seized and message transmission will take place. The message will be punched into tape at the LARP reperforator and will proceed through the tape transmitter to be transmitted, this time to the proper outstation if operation there has been resumed.

CONCLUSION

From the description above, it is evident that the successful functioning of a Plan 59 switching system depends to a major degree upon rigid adherence on the part of operating personnel to prescribed message format and operating routine. Deviations from proper format will generally result in failure to achieve the advantages of fully automatic operation, the importance of thorough operator training is thus emphasized.

From the maintenance standpoint, rapid diagnosis and localization of trouble conditions is required to hold equipment-down time to a minimum and prevent the accumulation of message backlogs. The provision for swapping out defective modules and chassis quickly is effective only when the trouble condition has been analyzed and the defective unit determined.

The description of equipment and system operation given above has been necessarily much abbreviated, although it is felt that all elements essential to a general understanding of the system have been included. No attempt has been made, for instance, to deal with the many safeguards and alarms which are necessary to protect against the loss or delay of traffic, although several of them have been touched upon incidental to the description of message processing. A detailed description of all system functions runs at the present time to several volumes.

* * * * *

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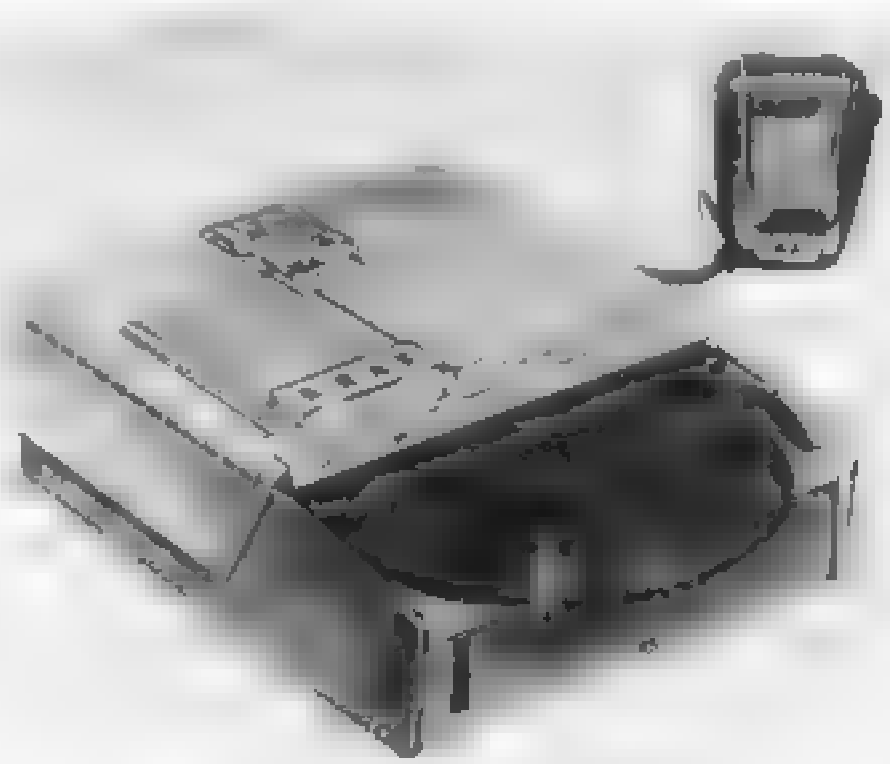
Technical Associates of Western Union — VI

The Gray Manufacturing Company

THE Gray Manufacturing Company of Hartford, Connecticut, is undertaking an expanded building and diversification program in 1961. The company plans to increase the sale of its commercial product line and add new proprietary products through an aggressive research and development program. Gray's current commercial products include the Audiograph dictation line and professional audio components.

Gray's new 1961 Key-Noter line of dictation instruments features the "Executive" dictator with dual tone recording, the "Secretarial" transcriber, and the "Voyager" battery model. The Key-Noter is a versatile, light and easy-to-use disc dictation instrument taking up no more desk space than the telephone. It features dual tone recording and true voice identity with the finest in quality sound reproduction now on the market.



Gray also undertakes specialized and selective contracts for electronic and communications systems and components that are compatible with the company's engineering and manufacturing capabilities.

An outstanding example is the assembly and production of the Western Union carrier bay, a fully transistorized multichannel teletype receiving and transmitting communications system. This contract included the building, wiring, assembly and subassembly of over 275 of these complex systems. Each carrier bay is over 10 feet high and can accommodate up to 20 channels that can, with modulating and demodulating equipment, transmit and receive teletype messages simultaneously within a 2000-cycle bandwidth.

The new carrier bay is an essential part of Western Union's modernization program and is currently being installed in Western Union offices throughout the country.

New Gray commercial products are in various stages of completion and scheduled for introduction in the next few months. These include an optical gauge combining the principles of television and advanced optics for automated measurements with a wide potential in industrial and military applications, a commercial audio-playback machine with a potential of 15,000 units in the first initial sales, a new audio-visual product combining Gray's excellent dictation equipment with a visual presentation system that has wide potential in consumer, business and industrial markets, and a confidential development contract for a new and revolutionary communications product.

E. L. NEWELL, Senior Project Engineer, Cable Equipment (Retired)

Surge Protection for Semiconductor Equipment

SEMICONDUCTOR components coming into wide use in telegraph equipment are subject to damage by much lower surge potentials than the older conventional components. Standard protective measures used in the telegraph system were designed to meet the requirements of the older apparatus. They are not generally adequate for semiconductor equipment and are being revised or supplemented.

Two distinct problems are involved. One concerns diodes and transistors in signal circuits, the other, diodes in power supplies associated with signal equipment.

SIGNAL LINE SURGES

Abnormal potentials appear on signal lines mainly as a result of nearby lightning hits on the line. Only rarely will damaging potentials occur on signal lines because of earth currents or power line induction or contact.

Line surges reaching terminal equipment are of various values and frequencies depending on the source of the surge and the nature of the line. However, from numerous tests the Bell Laboratories have established that these surges have a minimum fundamental frequency of about 1500 cycles per second with amplitudes decaying from peak to half value in 1 millisecond or less, and that a 10×600 microsecond impulse wave is a satisfactory equivalent for test purposes.[1] The 10×600 microsecond wave is one that rises to peak value in 10 microseconds and falls to half peak value in 600 microseconds. (See Figure 1.)

Lightning potentials are primarily line-to-ground but line-to-line potentials are developed because of circuit unbalance or when arresters on the lines do not break over at exactly the same time. Except in a very few cases, telegraph equipment is coupled to signal lines through transformers which eliminate any serious line-to-ground potentials as long as the transformer insulation to ground is adequate.

Lightning Arresters

Equipment in telegraph offices and on customers' premises normally is protected by arresters and instrument fuses located in the entrance cabinet or on the distributing frame in accordance with Western Union Specifications 544-E.[2] Instrument

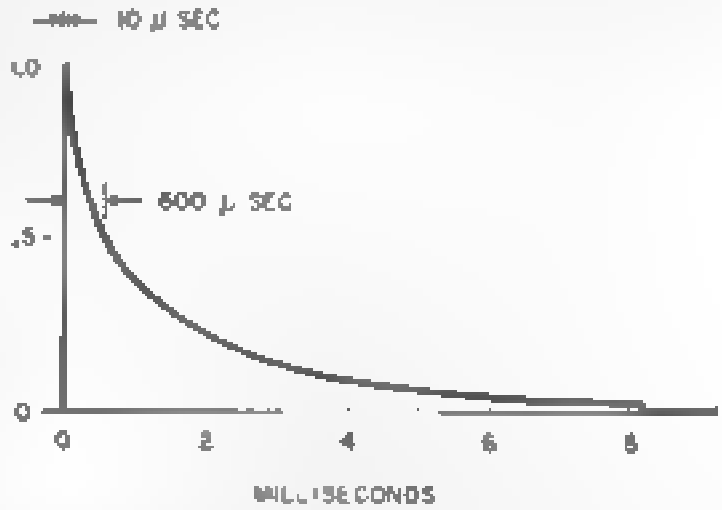


Figure 1. Surge impulse for testing

fuses are intended primarily to protect against fire and not fully to prevent damage to apparatus. With the older type of arresters there may also be a line fuse installed between line and arrester to disconnect the line in case of excessive arcing across the arrester.

Arresters in general use in telegraph installations are of the carbon gap type with a gap spacing of 0.028 inch (old white block WE-27) or 0.003 inch (new white tube WE-107-C). These gaps limit surge potentials to a peak value of about 600 volts and are the smallest gaps consistent with a reasonable amount of maintenance. Though not used in the Western Union system, there are available several types of arresters using metal electrodes enclosed in a glass tube with a small amount of gas. Some of these have surge breakdown values as low as 250 volts. While the gas tube arresters are less affected by moisture, dust, insects, and so

forth, than the carbon gap type, they cost about five times as much. They also have the serious drawback that their breakdown voltage may be greatly increased after excessive spark-over current flow caused by a nearby lightning stroke, thus leaving the circuit unprotected without giving any indication of arrester failure. Carbon gaps short circuit on failure leaving the circuit completely protected—and inoperative until the carbons are replaced.

Low-Voltage Protection

It does not appear practical at this time to revise the present over-all primary protection system in order to meet the low-level requirements of semiconductor equipment. The more practicable method is to consider each type of semiconductor installation by itself and, where necessary, to design the circuit to be inherently safe or to add protective elements.

Safety from damage by the 600-volt surge peaks let through by the standard carbon gap arresters may be designed into a circuit in several ways. For instance, transformers may have cores that saturate when normal signal levels are exceeded, the upper frequency cutoff point of the circuit may be made sufficiently low to reduce surges to a safe level, or semiconductors of safely high voltage and current ratings may be used. When such measures provide only partial protection, or are impractical or too costly, voltage limiting elements may be inserted in the circuit.

The fundamental circuit for using these protector elements as surge limiters is shown in Figure 2. The required voltage rating of the limiter is determined mainly by the requirements of the vulnerable components. The current rating depends on the safe current capacity of the limiter and on the attenuation of the preceding nonvulnerable components which in some cases may need to be increased by the insertion of a resistance or an attenuator pad.

Silicon Zener diodes, special selenium diodes, and gas glow tubes are the most promising elements available for low-voltage surge protection. The diodes are used as surge limiters by taking advantage of their very high resistance at inverse voltages below the so-called "avalanche breakdown" point, and their ability to maintain a nearly constant voltage drop beyond the breakdown point. Gas glow tubes have a somewhat similar characteristic. The gas tubes function on either

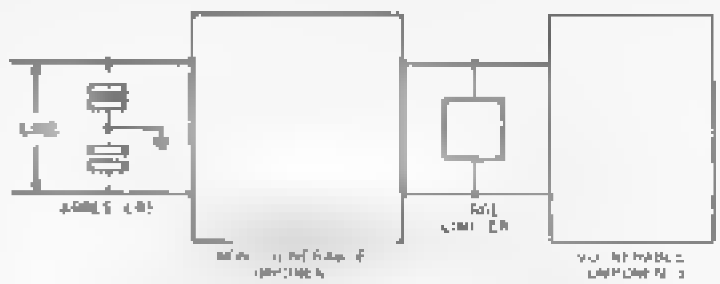


Figure 2. Typical circuit with surge limiter

polarity while the diodes must be used two in series, back-to-back, in order to protect against surges of either polarity. The Zener diodes have the best surge limiting characteristics and the least physical size, but are by far the most expensive.

The voltage curves in Figure 3 show how effectively the diodes and gas tubes limit 600-volt, 10×600 microsecond surges, applied to a simple version of the circuit of Figure 2.

Because of their sharp breakover and small change in voltage drop with increasing current, the Zener diodes do not show much rise of the surge peaks above their rated voltages, 20 and 45 in this case, when used with the lower values of preceding resistance. Zener diodes are available with any desired voltage rating between 6.8 and 200 volts.

The special selenium diode, SP105, has a reverse breakdown voltage starting below 50 volts but, because of the diode resistance, the voltage drop rises considerably as the current increases. The net result is an effective limit voltage considerably above the breakover point, and much dependent on the value of the preceding resistance *R*. The special selenium diodes are manufactured with reverse breakdown points ranging from 50 to over 1000 volts.

The gas glow tubes also show an effective limit voltage much above the breakdown point but for a different reason. Because the gas has an appreciable ioniza-

tion time, sharp surges rise to two or three times the breakdown voltage before current flow through the tube affects the surge. One-watt or 3-watt glow tubes of the lowest breakdown voltage, 60 to 75, are the only tubes likely to be of use as surge limiters.

The gas glow tubes and special selenium diodes require a preceding effective resistance of at least 200 ohms for satisfactory surge limitation to a definite voltage level.

For the short surges that get through the line arresters, the maximum peak current that the protector diodes can withstand varies nearly inversely with the inverse voltage breakover rating and directly with the junction area. Catalog ratings usually refer to continuous current operation and bear no relation to surge current capability. For instance, Motorola 1.0-, 1.5- and 10-watt silicon Zener diodes all have the same 0.00635 square inch of junction area and, for a given voltage rating, have the same surge current limitation. The table below gives the recommended maximum surge current for some Motorola Zener diodes.

Catalog Rating Watts	Junction Area Sq. In.	Inverse Breakdown Voltage	Max. Peak Surge Current Amperes
1 to 10	0.00635	20	16
1 to 10	0.00635	45	7
50	0.0156	45	14
50	0.0156	120	5

These Zener diodes will, in fact, usually pass more than twice the recommended maximum current without damage. For the same junction area the selenium diodes have approximately one one-thousandth the current capacity of the silicon Zener diodes.

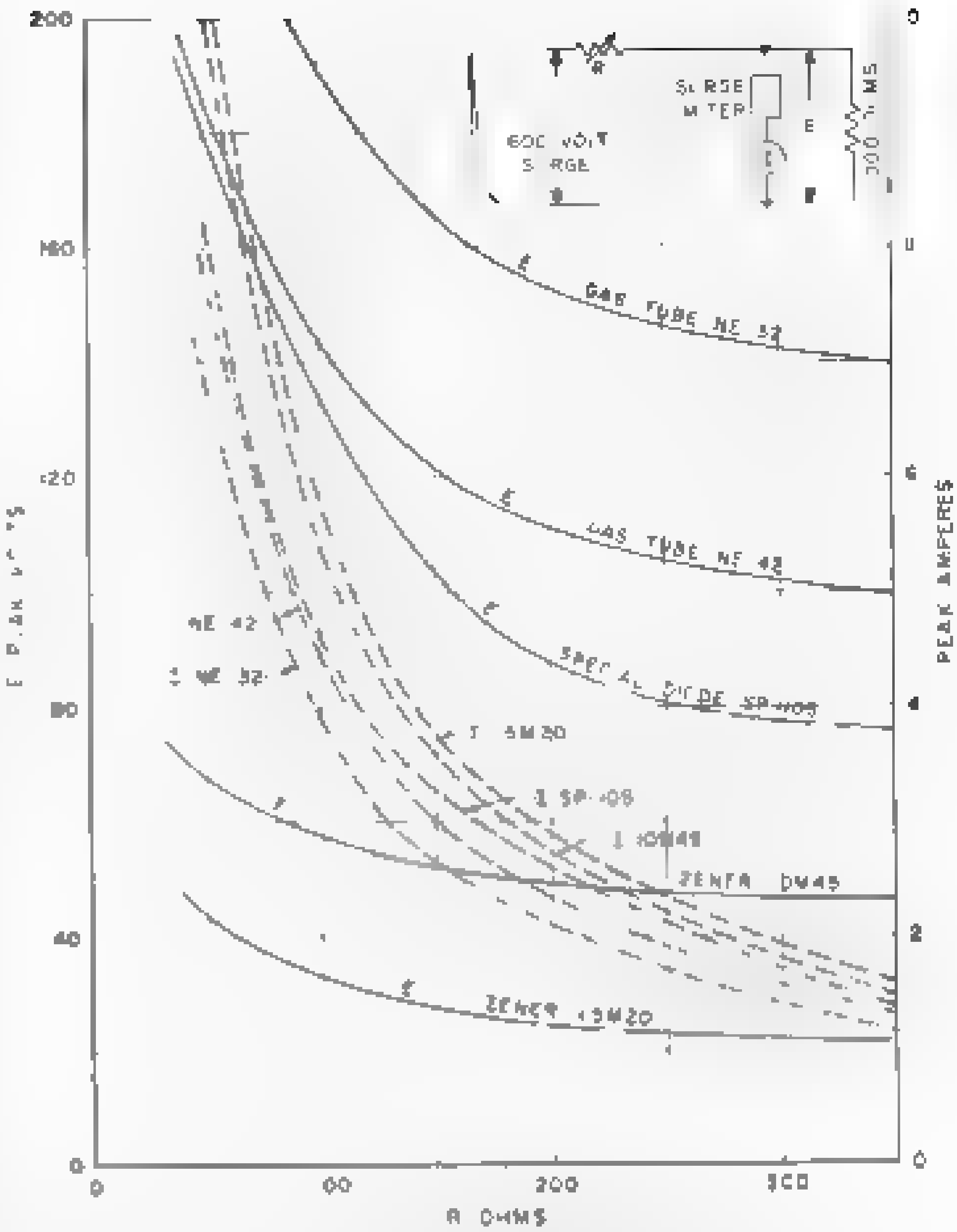


Figure 3. Surge limiter characteristics

The 1-watt and 3-watt neon glow tubes are over when the current is above 3 or 4 amperes. Surprisingly, however, these tubes will withstand hundreds of 10×600 microsecond surges with a peak current of 20 amperes without apparent damage to the tubes.

The capacitance of the surge limiter may have to be considered in some circuits. The 1.5M20 Zener diode has a capacitance of about 0.002 microfarad, somewhat less for the back-to-back series combination. The special selenium diodes are much higher, about 0.04 microfarad for the SP105 back-to-back combination. The capacitance for the diodes varies directly with the junction area and inversely with the inverse breakdown voltage. The neon glow tubes have a low capacitance of the order of 10 micro-microfarads.

In the simple circuit shown in Figure 3.

a protector to limit surges to a given peak voltage may be selected by simple calculations. Actual signal circuits, however are normally much more complicated, and the surge peaks that may reach the various semiconductor components, with or without protectors, are very difficult to calculate. Also, catalog ratings of transistors and diodes provide little useful data on maximum safe voltage and current surge levels. In general, diodes will withstand single instantaneous transients 150 to 200 percent of the continuous catalog ratings. Transistors are subject to at least five types of breakdown[3] some of which may occur considerably below catalog rating depending on circuit configuration. For instance, maximum safe Vce (collector emitter Voltage) decreases as resistance is increased between base and emitter terminals.

Surge Tests

Because of the many factors involved and the lack of uniform semiconductor rating standards, a test of the individual circuit is the most practical way to determine whether the semiconductor components are of adequate rating, and what protection may be required

A circuit for generating the 10×600 microsecond wave for surge tests of telegraph signal circuits is shown in Figure 4. When the key switch is operated, capacitor C is charged on each revolution of the synchronous motor-driven commutator and then discharged into the circuit under test in a series of impulses, 30 per second, that may be easily locked in on an oscilloscope sweep. The 500-ohm resistor between the back contact of the key switch and the commutator removes any charge remaining on C after the operation of the switch. A Variac control on the a-c power input permits adjustment of the test wave from zero to the 600-volt peak assumed as the maximum let through by the 0 003-inch carbon gap arresters normally protecting telegraph equipment. The capacitor C of 1.6 microfarads and the 1.7 millihenry series inductance are values selected by trial to give the desired 10×600 microsecond waveshape when discharged into the normal 600-ohm impedance of telegraph apparatus

In making tests the impulse is applied directly to the signal equipment terminals without any line, thus simulating reasonably well the worst condition in which the equipment is close to the line arresters. Usually, tests will need to be made with impulses of both positive and negative polarities. Damage to components can be kept at a minimum by making tests with reduced surge potentials until the effect on each component can be measured and any required protection inserted.

All types of telegraph signal equipment, in use or under development by Western Union and employing semiconductor components that appear liable to damage by line surges, have been tested to measure their vulnerability Most types already are safe Some are being made safe by imposing a lower limit on the size of normally used input attenuator pads, and some require the insertion of a protective element for complete safety if they are ever used in exposed locations When

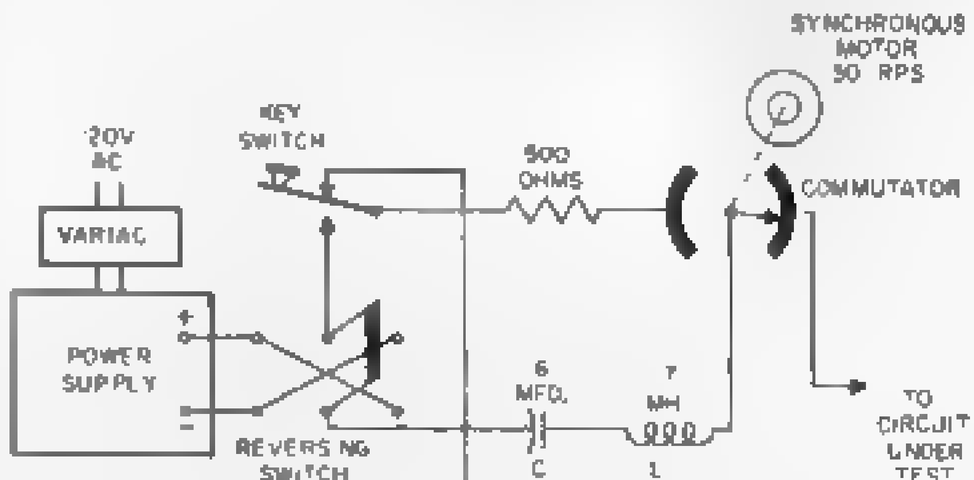


Figure 4. Surge impulse generator

safety is marginal, present practice is to defer specifying the insertion of surge limiters until a period of field service has indicated a definite need for them

POWER LINE SURGES

Abnormal potentials on secondary power circuits to consumers may come

from nearby lightning or from surges set up by control equipment or distant lightning effects in the primary distribution lines.

General experience of power distribution companies has been that abnormal potentials on lines to consumers are not, except in special cases, of sufficient magnitude to damage motors, heaters and such power equipment. This is because these lines are normally short and are lower than surrounding trees and buildings, and usually have one of the service conductors grounded. Protective elements usually installed on the primary side of the distribution transformer greatly reduce surges before they are transferred to the secondary. Also, surges are further attenuated by the power meter and in the local conduit wiring.

While there have been many investigations to determine the incidence of surges great enough to damage power equipment on lines to consumers, there appears to be no record of the actual magnitude of these surges, nor data on the frequency of surges too small to affect power equipment but large enough to endanger semiconductor rectifiers.

Over the past five years Western Union has had several thousand silicon and germanium diode rectifiers of various types in wide use with no reported failures due to lightning or other line surges. Also, there is no reported use of power line lightning arresters anywhere in the telegraph system. It seems safe to infer, therefore, that lightning or other power line surges are not usually of sufficient magnitude to damage rectifiers made in accordance with present specifications.

However, in the future, there may arise situations in which abnormal line potentials are unusually large, or maintenance of service is especially important. In such cases the installation of surge protectors on the secondary power line might be economically justified.

Secondary Power Line Protectors

For use on lines of up to 175 volts rms there are available protectors that break down at about 1600 volts on steep-front surges, and then return to the nonconducting condition within a few microseconds after the surge is discharged. These arresters will provide adequate protection if there is sufficient attenuation between the arrester and the equipment to reduce the residual surge to a safe value.

When further protection is required, standard carbon gap arresters may be added. The WE107-C 0.003-inch gap or WE107-B 0.006-inch gap arresters will limit surge peaks to about 600 volts and 900 volts, respectively. However, some device, such as a varistor with a minimum resistance of about 15 ohms at 120 volts, must be connected in series with the carbon gap to interrupt the 60-cycle short-circuit current after the surge is discharged.

To insure that the 1600-volt protectors break down first and that only a limited surge reaches the carbon gap arresters, there should be some regulating impedance between them. About 20 feet of steel conduit is usually sufficient.[1] The carbon gap arresters may be used without preceding higher voltage protectors if the line surges are not likely to exceed about 1600 volts.

There are also available gas tube arresters such as the Westinghouse XK642 which breaks down at about 900 volts on steep-front surges. In general, the gas tube arresters, because of their ionization time, have a surge breakdown voltage that is considerably above the direct-current breakdown. Like the neon glow tubes, the gas arresters do not fail safe.

Rectifier Internal Transients

Semiconductor rectifiers in present use in the telegraph system have not been designed with any particular regard to safety from damage by abnormal line potentials. Their freedom from such damage is, rather, a by-product of design to avoid damage from rectifier internal transients. These transients have little effect in vacuum tube or selenium rectifiers, and their importance in silicon and germanium rectifiers was not generally recognized until they caused numerous diode failures

in Western Union installations in the field in 1956.

Transients with peaks up to ten times the normal rms secondary voltage may occur when normal line voltage is applied to the rectifier. The tendency to develop these transients depends mainly on the transformer characteristics. The reverse voltage and forward current peaks that such transients may impose on the diodes depends on the type of rectifier and filter, and it should be noted, particularly, that in rectifiers with a center-tapped secondary the transient peak will be twice that in half-wave rectifiers or full-wave bridge types. In some cases there may also be a transient when the load is switched, but it is usually of lower peak value

With a resistance or choke input filter the diodes are subjected to a reverse voltage that may approach the peak value of the maximum transient that the full secondary can develop, that is, up to ten times full secondary voltage. A capacity input filter or a battery load, however, offers a low impedance path to the secondary transient thus greatly limiting the reverse voltage build-up on the diodes. The resulting current surge through the diodes normally is well below the allowable maximum.

Internal Transient Protection

For rectifiers with capacity input filter or battery load, a continuous PRV (Peak Reverse Voltage) diode rating equal to the full secondary normal a-c peak voltage is usually adequate. In some cases a small resistance in series with the diodes may be required to hold the current surge to a safe value. For resistance or choke input filters, general practice is to use diodes with a PRV rating approximately three times the normal a-c peak voltage of the full secondary except where internal transients are known to be low, or adequate transient suppressors are used.

The development of internal transients can be minimized by careful design; for instance, using a transformer with low magnetizing current. Transient voltage peaks may be kept low by shunting a capacity, usually 1 to 3 microfarads, across the secondary winding. The special selenium diodes, previously mentioned as transistor protectors, are also effective surge suppressors in rectifiers when shunted, back-to-back, across the secondary or, single-unit, across each of the silicon or germanium diodes. The capacity shunt on the secondary has served very effectively on some types of rectifiers widely used by Western Union, but there has been no experience with the recently available special selenium diodes.

Because of the many factors involved, the required ratings for the various rectifier components, including protectors, can best be determined by oscilloscopic examination of the transients developed by switching on and off the normal line voltage—and also the load. Since field experience has shown that ratings selected to withstand the internal transients are normally safe from damage by lightning or other power line surges, it is unnecessary to make the more difficult line surge tests.

Some of the power supplies recently designed for telegraph use have a very narrow margin of safety from damage by internal transients and probably also by power line surges. Here again, as in the case of signal equipment, experience in the field gives the final measure of safety that should be built into the rectifiers or provided by surge protectors.

Design Based on Field Experience

Since field experience is a particularly important factor in the design of semiconductor equipment for safety with economy, the need of a good line of communication from the field to the design engineer is apparent. Any large number of failures in one type of equipment will undoubtedly get immediate attention, but reports of smaller isolated failures are likely to be slow or never to reach the engineer. In order to improve this situation, a routine is being set up in which failures of semiconductors in specified types of equipment are to be immediately reported by field personnel, through Maintenance and Operations, to the interested engineering section. These re-

ports will state the nature of the failure and whether it appears to result from initial power application, power fluctuations or surges, lightning, or other unusual conditions. It is believed that current information of this nature will facilitate rapid design improvement.

References

1. Electrical Protection [illegible] HAYS, Jr., Commun[illegible]
2. [illegible]
3. [illegible] Breakdown [illegible]

E. L. Newell was graduated from Union College with the degree of B.S. in E.E. in the class of 1918 and received the E.E. degree from the Graduate School of Columbia University in 1922, his studies having been interrupted by two years' service in the U. S. Navy. He joined the Transmission Research Division in 1922 and has since been engaged mainly in the field of submarine cable transmission. His work has included supervision of the field work in connection with the duplexing of the Bay Roberts-Horta loaded cable; development of a 2-channel FM carrier system for short submarine cables; and more recently much of the mechanical design and construction of the submerged repeaters for non-loaded cables and of loading coils for the repair of loaded cables. He has also been active in the development of equipment for the elimination of radio interference originating in the telegraph system. Mr. Newell is a member of AIEE, ASA, Tau Beta Pi, and Sigma Xi.

HARLEY M. WARD, General Supervisor Plant Engineering Power (Retired)

Rectifiers As Dividend Sources

This article, while of chronological nature regarding rectifier power developments, is not intended as reminiscence, but rather to emphasize the ultimate importance of small economies and to accent certain lessons that can be learned in the School of Experience, since these may be as easily forgotten as those taught in other schools.

In this age of nuclear physics, space exploration, communication via man-made satellites and other highly technical research, it is perhaps a bit presumptuous to attempt to demonstrate that dividends may be available from sources not requiring integrated data processing techniques to uncover them.

The late Dr. Charles F. Kettering, the personification of Research at and for General Motors for nearly 40 years prior to his retirement in 1947, was a forceful speaker, prone to use a generous proportion of very strong language on practically any and all occasions. Mr. Kettering at one time discussed the purposes of research and engineering, particularly as applied to industrial corporations, somewhat as follows: Expressions such as new product, increased reliability, automatic control, better service, lower fuel consumption, easier maintenance and the like, he said, were fine for advertising purposes after the engineer had devised some new product, manufacturing technique or assembly method, but that the basic purpose behind his employment was higher profits.

The vast majority of people, engineers included, he continued, felt that the ultimate in success was "to make a million," but to do this, either for themselves or their employers, they thought they had to make a major invention, or find and develop some one big business opportunity which would produce the desired jackpot. This was not only difficult, but highly improbable in the majority of cases, whereas if one went about it properly, it was so blankety-blank easy to make a million dollars that anybody present should be able to do it repeatedly. Mr. Kettering's formula for this was to "concentrate on making dimes, nickels or even pennies in manufacturing costs or operating expenses, but applicable to items produced and used in large quantities, or over extended periods of time. The cumulative total of such economies would reach the million dollar goal a blankety-blank lot sooner and more often than the one shot efforts."

The basic truth of Mr. Kettering's thesis was demonstrated when calculations were made about 1925 to provide data relative to the actual value of higher operating efficiencies on motor generator sets. A very limited improvement in efficiency was found to be generally more than adequate to offset any price differential which might exist between quotations and make it much more profitable to procure the higher efficiency sets. That this was so could be primarily attributed to the fact that the machines would normally be operating for many hours per day, or per year. Motor generator sets had of course superseded primary and storage batteries as the major source of d-c telegraph potentials because of the economies involved in installing, maintaining and operating them as compared to batteries. However, there were practical limits on the peak efficiency which might reasonably be expected from motor generators, particularly in the relatively small ratings of 300 to 1500 watts, then used in the majority of cases by Western Union. This clearly indicated the desirability of finding more efficient means than motor generators for converting a-c power to d-c, but the search for this had been going on for a long time.

The development of radio broadcasting can no doubt be given much of the credit

for the breakthrough that finally came. Several new types of rectifier elements appeared, designed to eliminate the need for plate batteries on radio receivers. The majority of these were limited in current capacity to the requirements of such service and had rather poor regulation characteristics, but were capable of d-c output voltages sufficiently high for telegraph power purposes. Notable among these were Types 82 and 83 full-wave mercury-vapor rectifier tubes with coated filament cathodes. These had peak inverse voltage ratings of up to 1400 volts alternating current and output current ratings of 0.125 and 0.250 ampere direct current, respectively. The major advantage of these tubes was that the voltage drop through them was only about 7 to 10 volts and relatively constant for all values of load current, so that good voltage regulation and efficiency were possible and primarily a question of liberal transformer and filter inductor design.

Individuals in several engineering groups at Western Union were experimenting with the Types 82 and 83 tubes as replacement for chemical rectifiers in use to a limited extent for single circuit operation and introduced two or three types using them, with a straight capacitor filter. This type filter produced no undesirable inductive effect on telegraph signals, but gave such poor voltage regulation and peak plate current values that the useful load value was limited to 0.125 ampere or less from the 0.250-ampere Type 83 tube, still restricting the use to a single circuit in most instances.

At about this same time, General Electric was making a survey to determine the potential market for two full-wave mercury-vapor tubes with current ratings of 2.0 and 6.0 amperes respectively, which they had developed for industrial use. They brought in samples and offered to assemble two small rectifier cabinets with suitable transformers and tube sockets to facilitate laboratory tests, and to provide additional sample tubes for such field tests as we might care to make.

Our development of rectifiers began essentially as a depression activity with these new GE tubes and with the previously mentioned Types 82 and 83. Soon other manufacturers, such as Westinghouse, Raytheon and Electrons, Inc., appeared with laboratory made samples of mercury-vapor and argon gas tubes which they were developing. The author wishes to emphasize at this point that the ultimate success of the early rectifier development and other related work was due in very large measure to the ingenuity and inventive thinking of Western Union engineer A. A. Steinmetz (retired), who not only originally recognized the full potentialities of rectifiers using these tubes, but handled essentially all of the transformer and filter design and conceived many novel solutions to other problems that arose.

Progress was also materially aided by the interest and active encouragement of former Vice Presidents G. M. Yorke and F. E. d'Humy through depression conditions, when restrictions on cash expenditures were so severe that most of the design and production of prototypes for field test had to be tailored to fit specific emergency conditions that arose, where some minimum expenditure had to be made in any event and if test rectifiers could be provided within that limit, approval was possible. This tended to result in a multiplicity of types and also led us into projects where the rectifiers accounted for only a portion of the overall problem.

An example of this was the substitution of rectifiers for amplifier plate supply, land-line and cable transmitting batteries at Hammel Cable Station (New York) in 1934. Changes in amplifiers and other cable equipment were proposed to increase the capacity of the 1923 Horta and 1926 Bay Roberts "loaded" cables, requiring increased transmitting voltages and numerous additional banks of storage batteries. Space in the station, particularly the battery room, was at a premium. Rectifiers would solve the space problem, but had to equal batteries as regards constancy of voltage and freedom from interruption, without introducing interference which would be picked up by the ultrasensitive cable amplifiers.

The desired results were accomplished,

but required most of a year while an entirely new interrelated "continuous" power system was engineered, tested and installed. This system consisted of 3-unit motor alternator sets to supply alternating current to rectifiers, the alternator

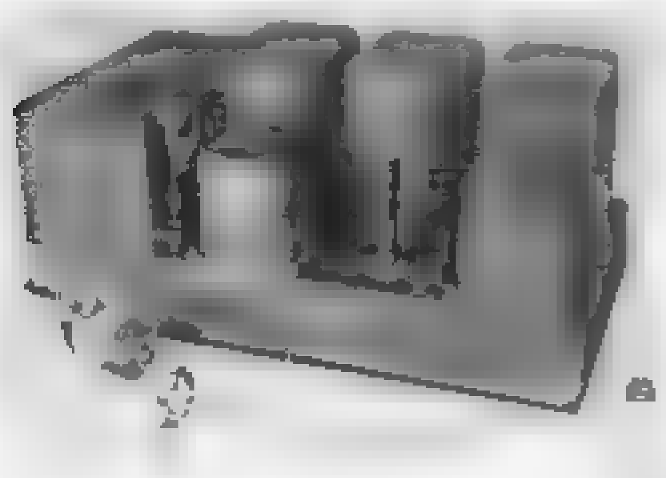


Figure 1 Cable amplifier plate supply rectifier, Hammel, 1934

being direct-connected to two motors, one alternating current for normal drive, the other direct current for emergency drive from the 120-volt station local battery during the interval between failure of the regular a-c power and starting of the station's emergency engine generator set. The alternators selected were small 3-phase units to permit use of 6-phase rectifiers, incorporating a novel interphase transformer arrangement[1] which doubled the ripple frequency from 360 to 720 cycles and reduced its amplitude by 75 percent.

This essentially eliminated the possibility of ripple voltage interference with cable signals, which were of only about 60-cycle frequency. Figure 1 shows one of the three types of rectifiers developed for this project. Special voltage regulators had to be devised for the alternators, as there were no electronic or other type regulators on the market with sufficient sensitivity of control to meet the requirements. A regulator previously developed for control of a direct-current generator at Bay Roberts,[2] using electronic amplification of voltage changes and a magnetic amplifier to vary the a-c voltage applied to a mercury-vapor rectifier tube in series with the generator field, could not be used on the Hammel alternators because the single phase a-c load for the field "booster" would have unbalanced the 3-phase output.

The regulator finally devised, after tests of at least 20 different combinations, used the armature of a fractional horsepower d-c motor in series with the alternator field, with d-c input from the station battery and electronic control of the motor field. Changes in the motor field varied the speed and the back emf of the armature, with resultant changes in the alternator field current. It was later discovered that the basic principle of this regulator, except for the electronic control, had been disclosed in a patent issued to Thomas A. Edison some 40 or more years previously.[1]

The experience and knowledge gained on the Hammel project were invaluable and facilitated the engineering of other "continuous" a-c power supply problems over the next 25 years, up to and perhaps beyond the Pittsburgh-Chicago microwave extension. However, prototypes of several subsequent standard single and polyphase rectifiers were completed and put into service,[3] despite the depression limitations on expense and manpower. Figure 2 shows an early version of the Type 603, using three GE full-wave 6-ampere tubes, built in 1934 for battery charging at Canso, Nova Scotia, after the regular charging generator armature burned out. The station had a spare armature on hand, so could continue operation of the generator set, but without spare facilities. Construction of the rectifier was approved, as it could be provided at less cost than repair of the defective armature and afforded more complete protection, as for example against failure of the motor windings, generator field coil or bearings on the generator set.

Similar rectifier units were later provided and installed at Newark, N. J., in lieu of larger motor generators, when increased load required additional capacity. The Newark units utilized argon gas tubes rather than mercury-vapor, for comparative test data.

During the first few months of operation of the Canso unit, there were numerous tube failures in which serious damage to the tubes was evident. Travel expense

to this rather remote location prohibited sending an engineer to investigate. General Electric was providing replacement tubes without charge and their examinations of the tubes returned indicated that in all probability only a maintained d-c

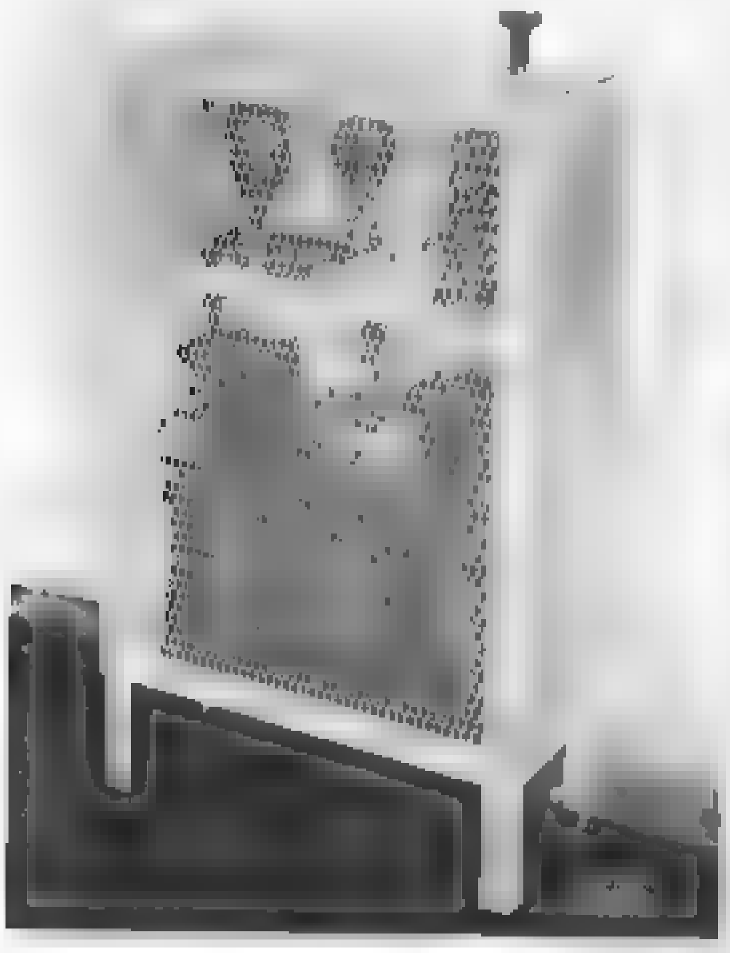


Figure 2. Early version of 6-phase mercury-vapor rectifier constructed for battery charging at Canso, N.S. [illegible]

arc inside the tube could account for the full extent of the damage. Quite by accident, after prolonged correspondence and "talk-wire" discussion with the station electrician, it was finally determined that the failures coincided with the starting and stopping of a large a-c motor used to operate an ice crusher on the Canso fish pier. As the town generator plant and distribution system were of small capacity, these heavy load variations caused voltage surges of sufficient magnitude to initiate a "backfire" in one or more of the tubes.

With a normal resistance or semi-inductive load the backfire arc would have been extinguished at the end of the half cycle and would have resulted in nothing more serious than the blowing of one or more fuses in the rectifier input. The batteries on charge, however, fed back into this short circuit inside the tube once it had been established and although the d-c current from that source was limited by charging rheostats to less than normal load values, it could perform very fancy burning and welding inside of the tubes. A suitable quick-acting breaker between the rectifier and battery corrected this. Such experiences proved the necessity for adequate field tests under a variety of conditions and with initial engineering supervision, if subsequent operating difficulties were to be avoided. Field assist-

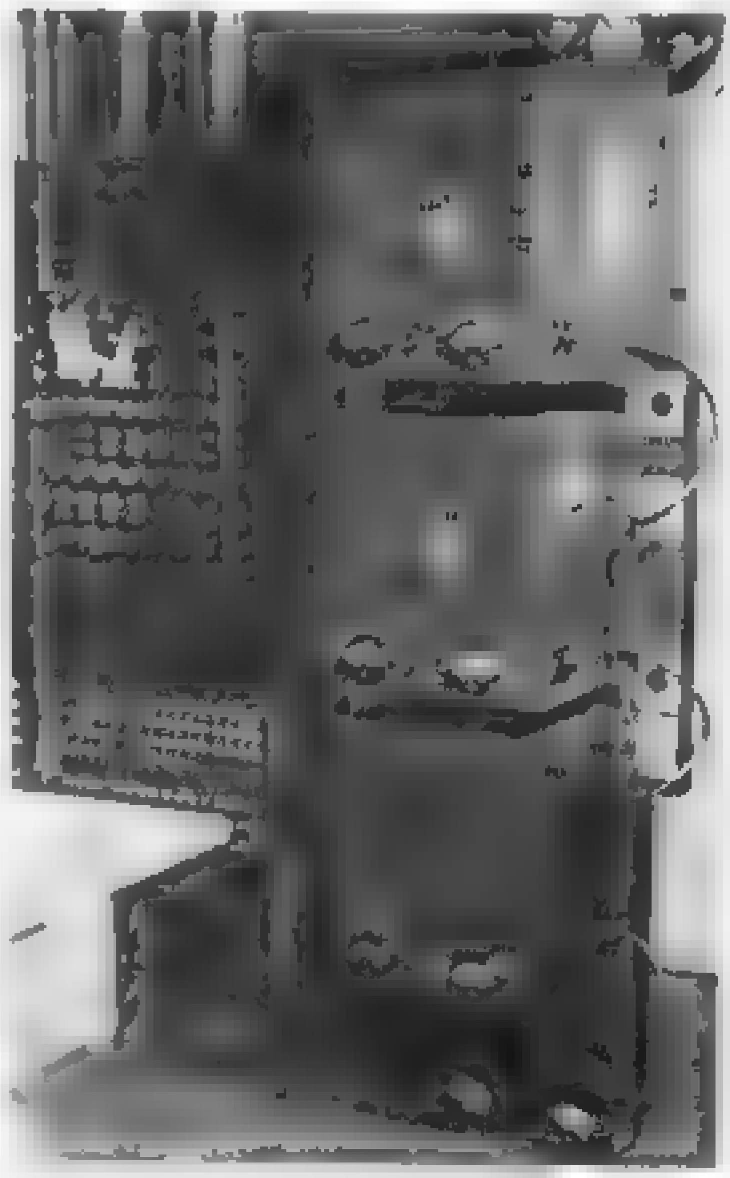


Figure 3. Type 603 mercury-vapor rectifiers with cord and plug switching facilities (right), assembled on rack for laboratory tests prior to shipment to Le Havre

ance and cooperation in such tests is essential and of inestimable value, but it cannot fully replace "on the job" observations by the design engineer.

Figure 3 shows a group of Type 603 rectifiers, assembled during World War II for

the Signal Corps to use at Le Havre, France, for cable equipment on a German cable, picked up and cut in the English Channel and diverted into that port. This group does not include filters, later added as standard equipment and mounted on separate rack panels above each rectifier. Filters were not initially included, because the 360-cycle ripple did not interfere with prewar telegraph circuit equipment or operation, with the very occasional exception of certain carrier circuits, power to which could be most economically filtered separately. Type 603 did not come into extensive use in Western Union service until after the war, when rapidly expanding installations of Type 20 Carrier Systems required additional d-c capacity in many large and medium sized offices. This expansion also dictated the eventual addition of filters to all Type 603 units.

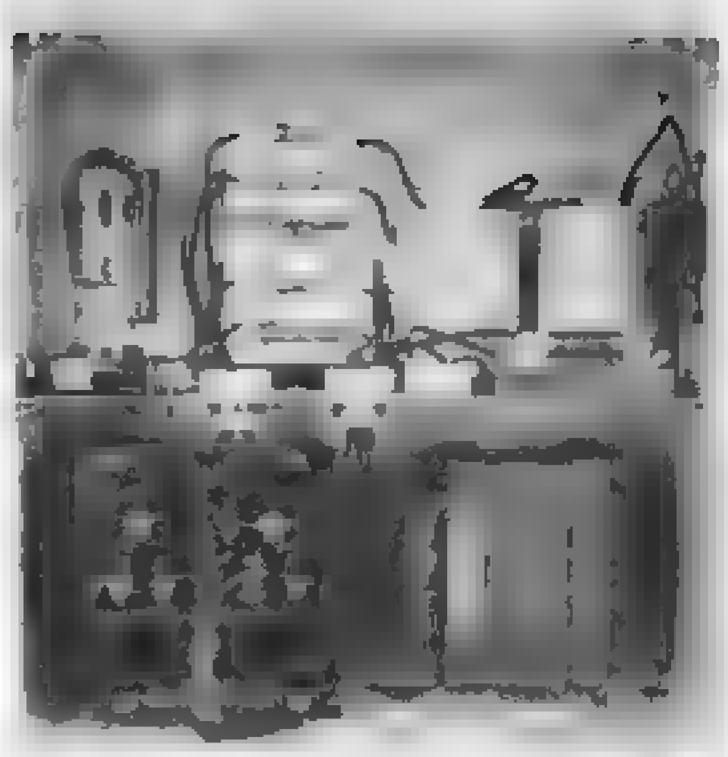


Figure 5. Early version of Type 10 mercury-vapor rectifier rated 2.0 amperes, 120 or 160 volts, using GE Type 16X697 tube

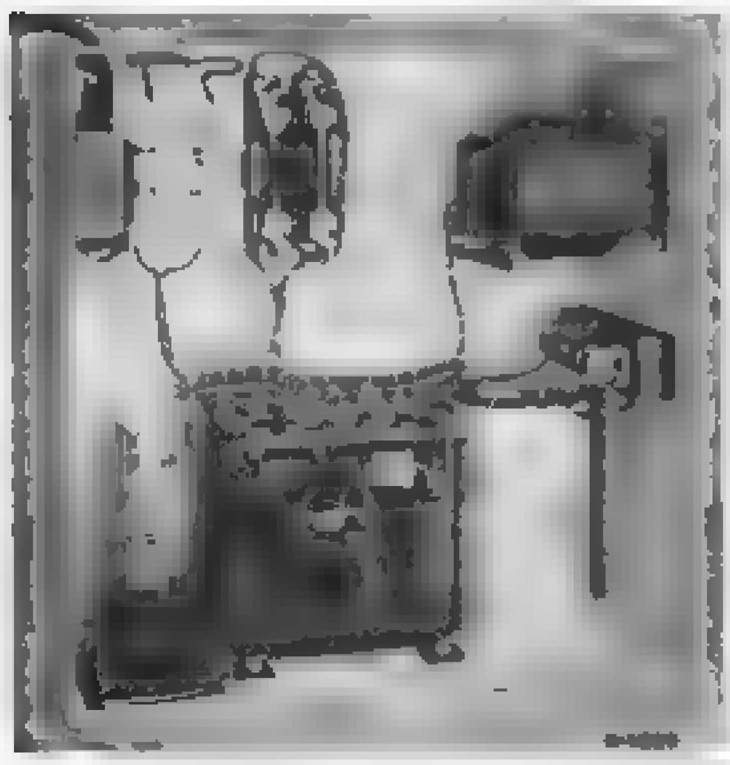


Figure 4. Early version of Type 63 mercury-vapor rectifier rated 0.25 ampere, 120 or 160 volts, using Type 63 tube

Prototypes of other single and polyphase rectifiers, later standardized, were put into service prior to 1936, but purchase and use in any appreciable quantities was initially limited to the smaller single-phase units using Type 63 and the 2-ampere GE tube, such as early versions of Types 63 and 10 Rectifiers shown in Figures 4 and 5. The assembly design of these was soon changed to "dead front," as shown in Figure 6 for Type 10. This design permitted tube and fuse changes to be made without possible contact with live parts. This feature was of prime importance, since probably the majority of offices where such units might be used were staffed by nontechnically trained employees. Lack of demand for the larger polyphase rectifiers was, of course, due to the prevailing economic conditions under which major load increases and office moves involving equipment changes of higher capacity were few and far between.

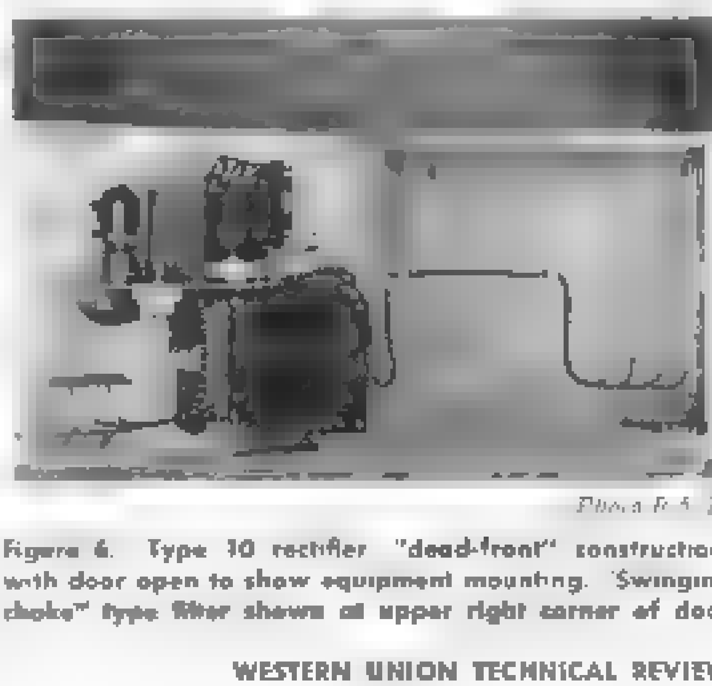


Figure 6. Type 10 rectifier "dead-front" construction, with door open to show equipment mounting. "Swinging choke" type filter shown at upper right corner of door

until at least 1940. Probably because of this lack of normal demand and the peculiar conditions under which prototypes for field test were specially designed to fit a particular need, rather than general service requirements, too many different "standard" types were originally designed to permit economical quantity purchasing and warehousing

Early Dividends

A study as to the possible scope of savings being effected was made late in 1938, about five years after the development was started, but only three years after delivery of standard units in any appreciable quantities began. This study was limited to only one of the new rectifiers, Type 10, rated 2 amperes d-c output at either 120 or 160 volts. This type was selected for the study as being most directly comparable in usage and capacity with 300-watt motor generator sets, which had previously been purchased and used in considerable quantities. Deliveries of the Type 10 rectifier began in 1936 and by the end of 1938 totaled 535 units, of which 435 had actually been installed. It was very conservatively calculated that total savings of $118,120 had been made through purchase and use of these 435 units alone, over this 3-year period. This included $104,400 saved on capital investment as compared to motor generator equipment and a cumulative total of $13,720 in power savings, which had reached an annual rate of $6090 at the end of 1938, with the 435 units in actual service. Purchases of this type had averaged 175 per year, even under "depression" conditions, and it was more than obvious that these "dividends" could be expected to continue and expand.

A more complete but equally conservative study was made in 1946 to cover the 10-year period from 1935 through 1944. This covered a total of 7168 rectifiers of 12 different types, 3 of which were of the earlier design using the Type 83 tube with capacitor filter and purchased through only the first 3 or 4 years of this period, before being consolidated with and superseded by improved designs with swinging choke filters. The combined cumulative savings for these 7168 rectifiers over the 10-year period was $1,356,120, of which $794,260 represented savings in capital investment and $561,860 the total cumulative power savings, which had reached a rate of over $90,000 per year at the end of this period. For a more direct comparison with the earlier 1938 study, a total of 1330 Type 10 rectifiers had been purchased and installed by the end of 1944. These accounted for $427,490, or about 30 percent of the above total of $1,356,120, and consisted of $319,200 in lower first cost plus $108,290 cumulative power savings over the 10 years, including of course the savings covered by the 1938 study. Only 108 rectifiers with ratings of over 2 amperes, two-thirds of which were pur-

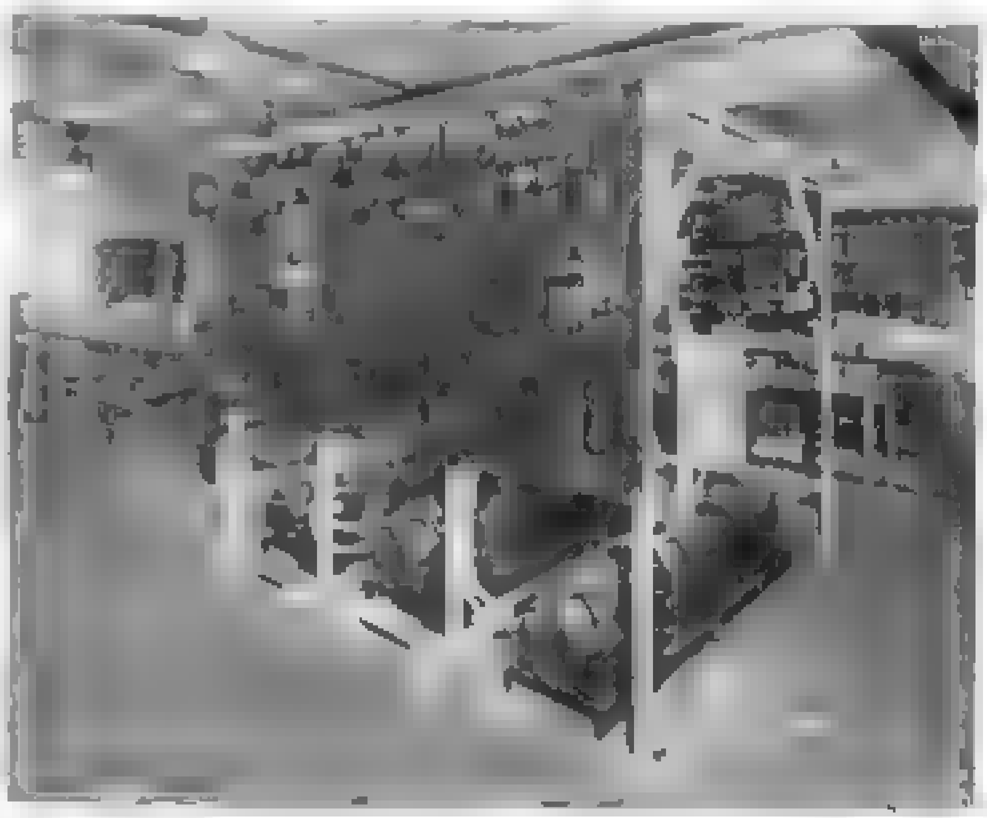


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Figure 7 North Sydney, N.S., motor alternators, control panels, a-c and d-c voltage regulators (rear), assembled for preshipment tests at 60 Hudson Street

chased during the last 3 years of this period were included. These represented total savings of $22,600 in first cost and cumulative power savings, or 1.6 percent of the total.

No credit was included for possible reduction in maintenance cost or smaller space requirements for the rectifier installations. Although these undoubtedly were substantial it was felt that while it could be demonstrated that the other estimates were conservative and accurate, it would be extremely difficult to establish a reliable basis of comparison for maintenance and rental costs, even to our own satisfaction. No attempt was ever made to estimate and summarize the economies resulting from design of many special rectifiers required for limited specific purposes such as cathodic protection, cable service, etc., for the same reasons.

During the ten years between 1942 and 1951, no major changes or additions to the "money maker" standard rectifier types were made. This was due to a variety of reasons including engineering manpower shortages during the war; pressure of work on special wartime and other projects, such as a "continuous power" rectifier plant at North Sydney (N. S.) Cable Station, Figures 7 and 8, similar to but much larger in scope than the earlier Hammel plant; special regulated[4] cable amplifier plate supply and transmitting rectifiers for Western Union use and for the Army Signal Corps on the Alaska Cables, certain Pacific and European cable facilities; engineering of an automatic unattended "continuous a-c" power plant for the New York-Washington-Pittsburgh microwave system,[5] including regulated selenium rectifiers for battery charging engineering of power plants for the reperforator program, plus numerous office moves and renovations which had been postponed during both the depression and the war. Also there had been no really significant change in type or characteristics of tubes, or introduction of new basic rectifier elements which would have justified any major redesign activities.

Late in 1951, primarily because of proposed special lease installations, it became apparent that a rectifier with larger capacity than Type 603 would be of value. This type had not come into substantial use until after the war and in the very occasional instances where loads of one or both polarities exceeded the 15-ampere rating of the 603, the loads were divided between two such units, with a common

Photo K-6534

Figure 8 Rear view of cabinets housing multivoltage cable transmitting rectifiers and patching panels for North Sydney "continuous a-c power" and rectifier project prior to completion of wiring

spare, as being more economical than purchase and stocking of larger units on a small lot basis. The Air Force Plan 51 Switching System lease involved potential ultimate loads which might require up to five or six Type 603 rectifiers. It was felt that such plants would be unduly cumbersome and complicated, particularly from a switching standpoint. As the company's power engineering group had been fully occupied with other important work for several years, it was decided to try to have an outside supplier design suitable units.

The company selected at that time had

filled numerous orders for several of our standard types, including the 603, and had a good record for meeting the requirements of our specifications. They were approached with the request to design a rectifier with twice the capacity of the 603 and with essentially the same characteristics as to voltage regulation, temperature rise, filtering, etc., and to submit a price on a lot of 12 such rectifiers. The price was satisfactory and an order was placed, on the understanding that we would have the right to review their proposed design and make tests on one assembled unit, either at their plant or in our laboratory, before final production of the balance.

In reviewing their preliminary plans, it was noted that the tubes proposed had a normal rating of 90 amperes. In the meantime, estimates of possible loads at the Air Force bases had increased and were then at a level where multiple installations of even the new 30-ampere units were in prospect. We therefore requested that the transformer and filter inductor ratings be increased to 45 amperes, as this would still be a most conservative load on the tubes. Very preliminary "breadboard" tests were made on one unit at the supplier's plant somewhat before the start of the 1952 labor troubles. During this period, the supplier completed the assembly of all units, requested and was granted permission to ship without inspection.

One "unit" had been shipped to the laboratory in accordance with the original requirement that we test and approve a prototype. It was found that the final assembly design had all components of one rectifier mounted on a single large rack plate and that two such rack plates were then mounted in a single, rather high rack cabinet, as partially shown in Figure 9. The weight of the individual rack plates, with all components mounted, made it impossible to assemble the plates in the cabinet without use of an "A" frame support and chain hoist. The components had been crowded into the most compact arrangement possible, with the initial result that they overheated to the extent that both rectifiers in one cabinet could not be operated at full load simultaneously. This was, of course, completely unacceptable for our service. A secondary fault was the fact that due to the congested assembly, a faulty component or a loose connection could not be located, corrected or replaced without major dis-

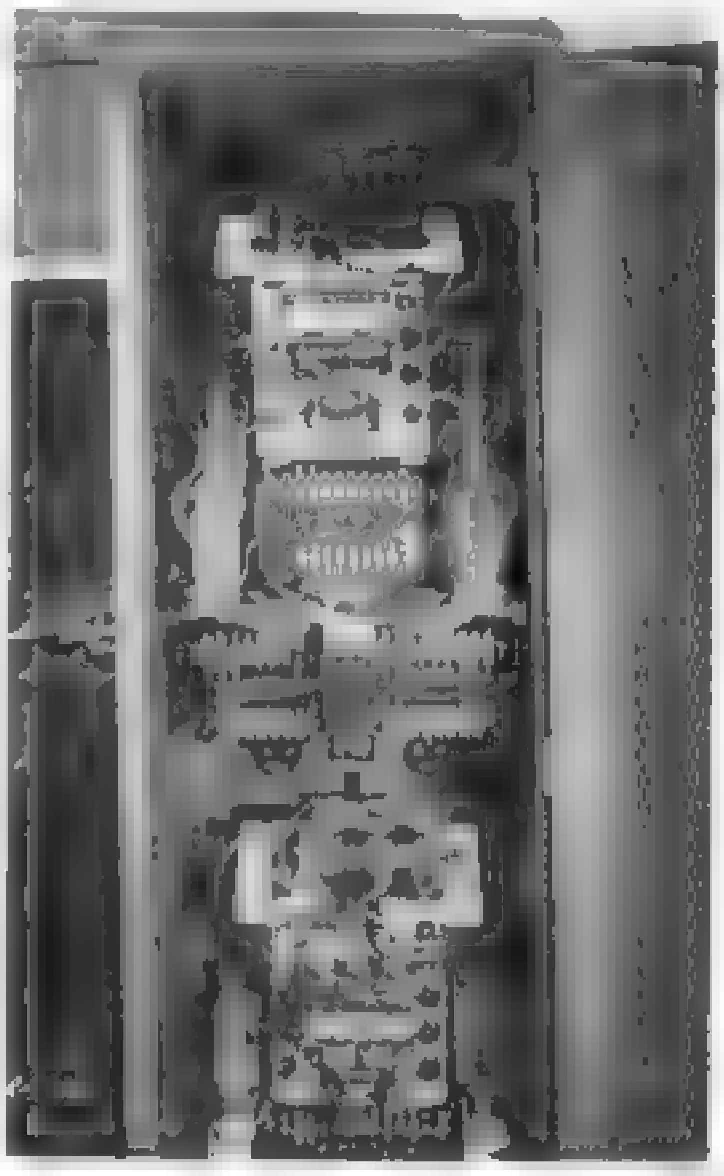


Figure 9 Partial rear view of cabinet housing two 45-ampere 120-volt tube type rectifiers. (Original commercial assembly design)

assembly of the unit involved, which would in turn require shutdown of the other rectifier unit in that cabinet and, in all probability, the entire office.

The overheating problem was corrected by forced ventilation, two small but high-quality blowers being added by us on top of each cabinet and connected, one to each rectifier. Ten of the 12 rectifiers were urgently required for pending installations and were put into service with this addition. Correction of the basic over-congested assembly faults was accom-

plished only by complete redesign, with components of only one rectifier mounted in its own individual rack cabinet. When the first such assembly was completed and tested, it was found that the rectifier would deliver up to 60 amperes at 120 volts, with temperature rise in the trans-

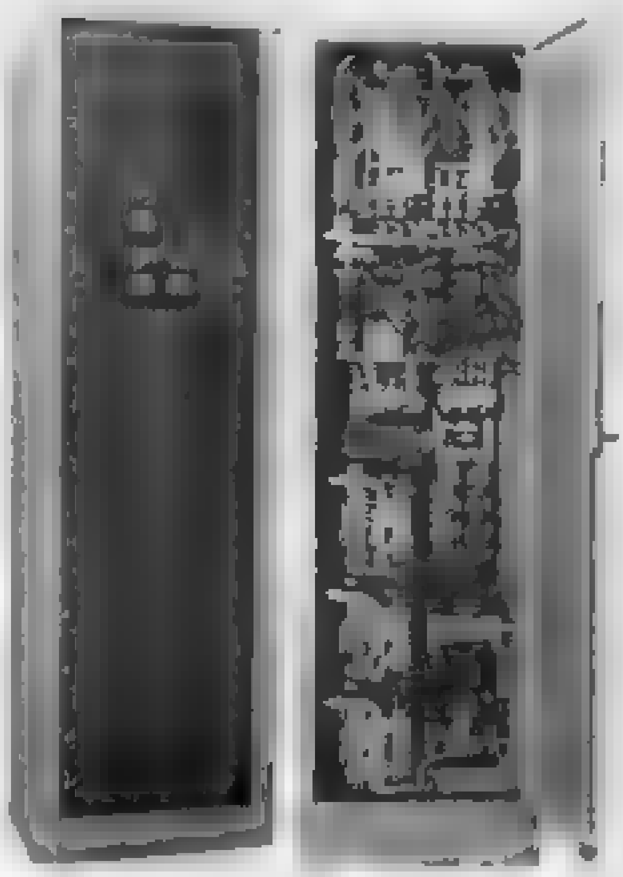


Figure 10 Prototype of 7291 Rectifier assembled in laboratory from components mounted on top panel only Figure 9

formers and filter inductor no higher than had been reached with the original 2-unit assembly at 45 amperes, after the forced ventilation had been added[1] Thus the last two of these "commercially designed" rectifiers were converted in the laboratory into units with one-third higher capacity and safe to use in telegraph company service, merely by application of conservative design principles, learned through experience. These two units were the prototype of Rectifier 7291, Figure 10, about 100 of which were purchased and put into service during 1956 and 1957

Silicon Rectifiers

The difficulties encountered in the above experience with "commercial" design left us strongly convinced that such procedure was extremely hazardous and should not be attempted a second time Introduction of germanium rectifier elements, followed shortly thereafter by news of a major "breakthrough" in the form of silicon diodes, gave warning, however, that our mid-'30 rectifiers were on the verge of obsolescence. All of the orders for our redesigned Type 7291 rectifiers had been obtained by a conscientious, cooperative and very capable supplier with progressive engineering concepts. As our own power engineering load was then very heavy in comparison to available manpower, it was evident that we would have to resort to commercial design again.

In 1956, during a visit to this supplier's plant to witness tests on some of the first of the Type 7291 units, the question of development of silicon units was discussed. At that time, they were of the opinion that although very rapid progress was being made in improvement and stabilization of characteristics, manufacturing techniques and production costs, it might be several years before silicon rectifier elements would be competitive with tubes, from either a cost or a reliability standpoint. They agreed, however, not only to keep our problems in mind, but to make some preliminary studies. We suggested that they concentrate on design of units in the following order and capacities at 120 volts direct current, as offering the maximum advantage to us in operating economies and elimination of certain objectionable features in the equivalent tube types

1. 40 to 50 amperes to replace Type 7291, 3-phase input
2. 15 to 20 amperes to replace Type 603, 3-phase input
3. 5 to 8 amperes to replace Type 66, 1-phase input.

The flexibility in output rating was intended to permit the most economical conservative choice of standard silicon assemblies which might ultimately become available, since these would probably not correspond with existing tube ratings

Less than a year later, in May 1957, the supplier advised that progress in silicon had been much more rapid than they had anticipated. Tentative design details, test data and prices for four prototype models of a 45-ampere, 3-phase silicon rectifier and estimated prices for future units in various quantities were submitted. The proportion of development charges to be borne by us, as reflected in the price for the initial four units, was extremely moderate. An order was placed for these, the first unit was completed and shipped to Miami, Fla., in August and placed in service in October 1957. Two of the remaining units were placed in service early in January 1958, one at Columbus, Ohio, and the other at Seattle, Wash. The remaining prototype was delivered to our laboratory for more detailed examination and test. Reports from the field were highly encouraging, but we did encounter burnout of one diode during tests on the laboratory unit. This was attributed, by the manufacturer from whom the silicon stacks had been obtained, to a defective diode which had nevertheless passed their rigid factory tests and further exhaustive tests of the completed rectifier at the manufacturer's plant.

In late spring of 1958, our stock of the 60-ampere tube Type 7291 rectifiers was nearing exhaustion and a decision had to be made as to whether more of them should be procured or whether we should initiate purchase of a sufficient quantity of the new 45-ampere silicon type to meet immediate needs. It was decided that although the field tests had not been as long or as exhaustive as might be desired, the comparative advantages of silicon in first cost and efficiency were more than adequate to warrant the risk. Delivery of 30 silicon rectifiers, Schauer Type SK-45120, Figures 11 and 12, was made in October 1958.

Our experience with this type of unit has been excellent except for serious damage in shipment to several of the units on this first contract, caused by excessively rough handling, which disclosed weakness in the transformer mounting. Experience has indicated that it may not be economically feasible to eliminate completely the possibility of shipment damage, nevertheless close attention must always be paid to this factor. Otherwise very serious losses may result from delay in starting service for lack of workable essential power equipment. After production started, it was also found advisable to add special current-limiting fuses to avoid complete destruction of the silicon stack in the event of failure of only one diode.

Schauer Photos 40450 and A-44096-3

Figures 11 and 12. Silicon Rectifier, Schauer Type SK-45120, front view (left), rear view (right). Note 2-phase silicon stack at bottom, immediately below main transformer

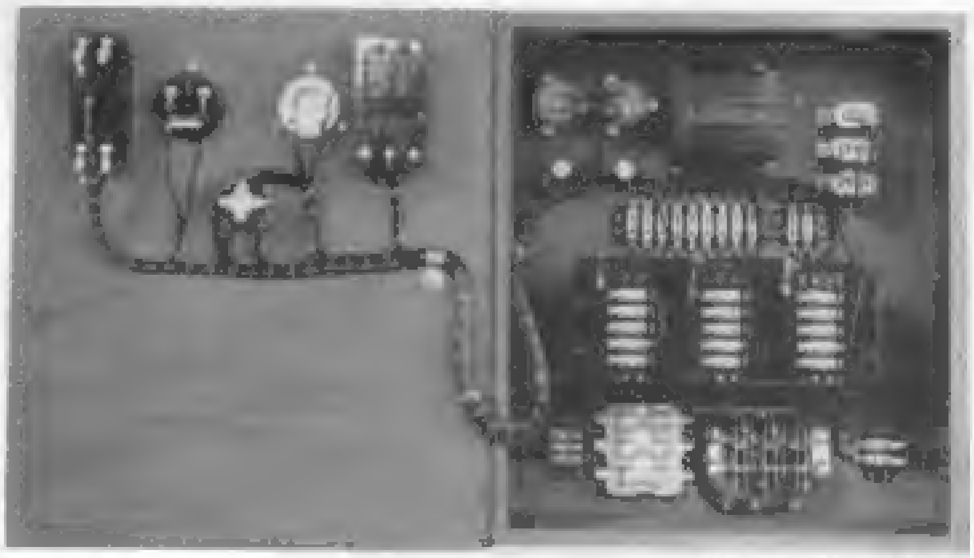
The circuitry and physical location of these fuses as selected by the manufacturer had inadvertently not been referred to us. Both were subject to improvement to best meet our service and maintenance requirements. The manufacturer requested return of all units to his plant for correction of the transformer mountings and this afforded an opportunity for relocation of and rewiring to the fuses. These few difficulties further emphasized the necessity for the closest possible coordination between the manufacturer and our engineers on all details of design.

Soon after delivery of the SK-45120 prototypes in the last half of 1957, prices were submitted on proposed silicon designs to replace tube Types 603 and 66, as we had requested. Prototypes of each were purchased and placed on field and laboratory test in 1958. Various proposed assembly designs were reviewed and orders placed for initial quantities of 25 Schauer Type SK-15120 and 50 Type SK-8120 silicon rectifiers as soon as warehouse stocks of Types 603 and 66 were low enough to warrant. Deliveries of these started in July and October of 1959, respectively, about one year after initial delivery of regular production SK-45120 units. Delivery of a second lot of 25 SK-15120 units began in October 1959.

Schauer Type SK-15120, Figure 13, was rated essentially the same as Type 603 which it replaced, 15 amperes at 120 volts d-c, with 3-phase input. However, the assembly design requires only one side of the rack for mounting and is also suitable for wall mounting. The filter is included inside the cabinet as an integral part of the rectifier, whereas Type 603 required both sides of the rack, plus mounting and connection of the filters on separate rack panels above each rectifier.

Schauer Type SK-8120, Figures 14 and 15, was rated at 7.5 amperes, 120 volts d-c with single-phase input, or 50 percent higher than Type 66, which it replaced. Mounting space and assembly design were similar, except that an ammeter, voltmeter and tap switch to monitor the output and provide three voltage step adjustments were added. These refinements had been omitted from Type 66 to reduce costs, but requirements of present telegraph circuits and equipment are more exacting and modern power supplies must keep pace with these. To do this, cooperation on design of several other types of silicon rectifiers, including two with magnetic amplifier control of output voltage, has been maintained, but cannot properly be included within the scope of this article, as purchases and service have both been too limited.

Four rectifiers of nominal 250-ampere, 120-volt d-c rating, but capable of output of over 400 amperes for limited periods, are currently installed at Detroit and under preliminary test and adjustment before being placed permanently in service to replace d-c service which the power company is eliminating. Other regulated output rectifiers of 25-ampere, 60-volt d-c rating have been purchased and are being installed to serve the new Telex loads.

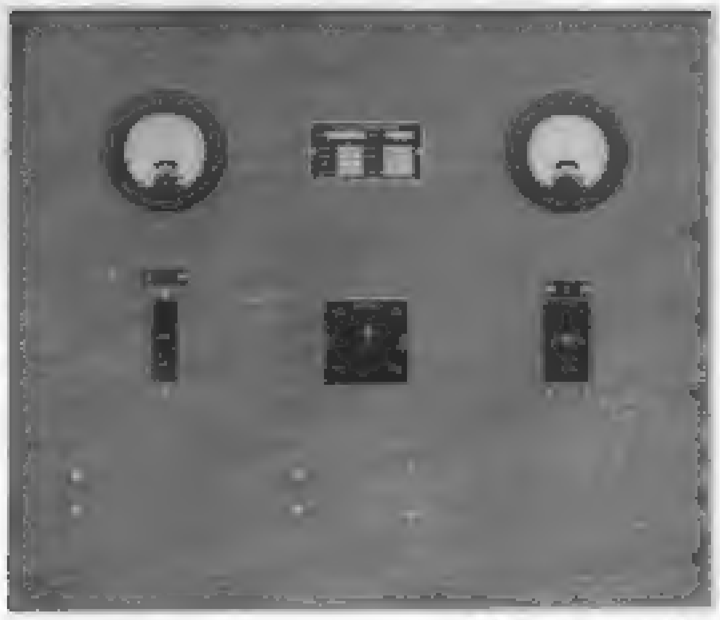


Schauer Photo 42171-1

Figure 13. Silicon Rectifier, Schauer Type SK-15120. Door open to show equipment assembly. (Closed view similar to Figure 14.)

Efficiency of these regulated types is lower than could be obtained with unregulated types, because of losses in the magnetic amplifier components.

It had been hoped that progress on development of the so-called "Thyratron" type, or "silicon controlled" rectifier, introduced about 1958, might be sufficiently



Schauer Photo 42171-4

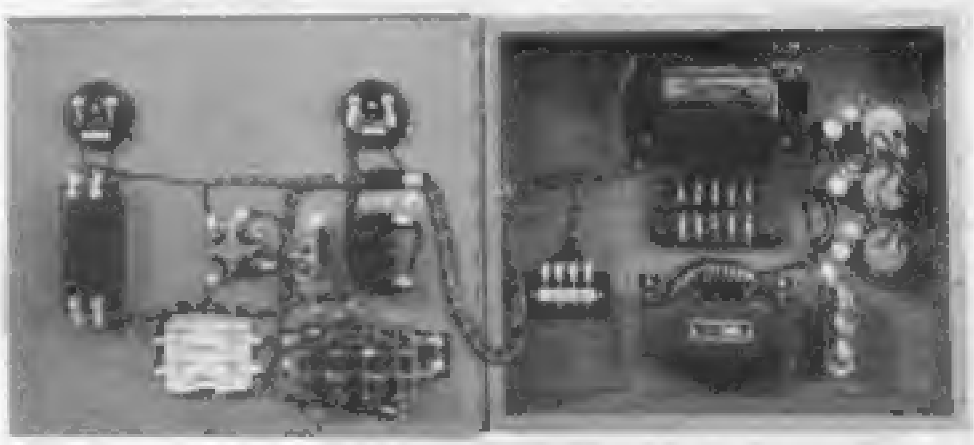
Figure 14. Silicon Rectifier, Schauer Type SK-8120

rapid to permit its use before we required ratings above that of the SK-45120. This type element differs from the ordinary two-terminal silicon rectifier or diode, in that it has a third "control" terminal and characteristics of construction which permit this terminal to control passage or blocking of current flow. The voltage drop is in the order of only one volt. Use of such elements would permit efficiencies comparable with those achieved in the present unregulated types and point the way to at least one possible path of future improvement in design which should be explored.

Efficiencies of three types of silicon rectifiers covered, as compared to the tube types which they replaced, as well as to typical average efficiencies of motor generators of comparable ratings, are shown in Figure 16.

Silicon Rectifier Dividends

Late in 1959, after delivery of a total of 91 of the 45-ampere, and 50 each of the 15- and 7.5-ampere silicon rectifier units, a third study was made to evaluate the benefits during the first year of use. This was based on the difference in first cost and on operating power costs of the silicon types as compared to the tube types which they replaced, rather than with motor generators. Savings in capital investment on the 191 units, after deduction of development costs, amounted to $34,298. Based on prevailing power rates at numerous offices where these types had been and would be installed, the calculated annual power savings on the "working" units only, excluding spares, was $10,300. Subsequently, an additional 100 units of each of the above three types have been purchased and delivered. These 300 units represent additional savings which, when calculated on the same basis and combined with the previous amounts, add up to new present totals of $85,702 saved in capital investment and power savings at the rate of $22,970 per year on the 491 units, during the 2-1/2-year period since the first of these "standard production" models were placed in service. As demonstrated by the 1938 and 1944 studies, these savings will continue to expand, year by year, as additional silicon or other



Schauer Photo 42171-2

Figure 15. Silicon Rectifier, Schauer Type SK-8120, door open

improved type rectifiers are purchased and installed. Because average service life of the silicon stacks was not available, no account was taken of probable reduction in tube replacement costs, although this may prove to be of considerable magnitude. Present levels of silicon element costs are only about twice those for tubes of equal capacity. There have been no reported failures to date of silicon stacks in actual service, since the installation of the original units in late 1957.

Although this article has dealt primarily with rectifier improvements and savings, there are many other fields where

other engineering groups have made economies which might not appear significant on a unit basis, but add up to impressive totals when over-all usage is considered. As an illustration, the new transistorized

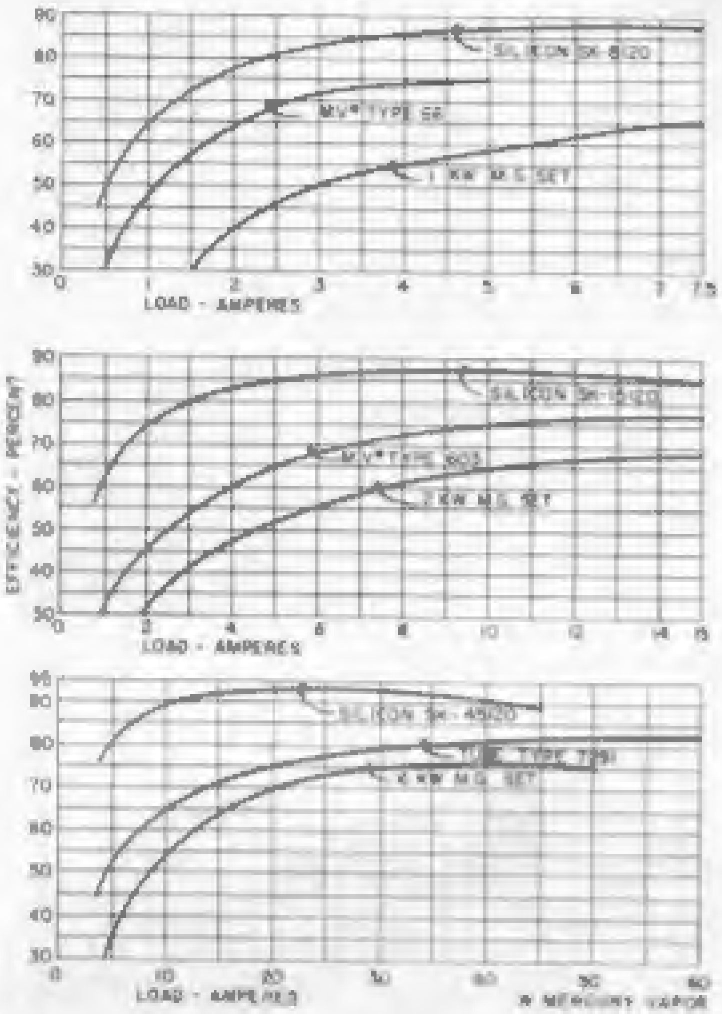


Figure 16. Graphs showing efficiency of silicon rectifiers as compared to equivalent tube types and motor generators

Type 60 Carrier Channel[6] reduces power requirements by 36 watts per channel as compared to Type 30. This represents less than 1-kw hour and an average saving of possibly only 2 or 3 cents per day, per channel. In comparison with the many other major benefits effected by this notable improvement in carrier equipment design, the power saving may well appear to be of minor consequence. It is left up to the reader to estimate, for himself, what this would amount to in total if it could be applied to all existing carrier equipment at present in service, or more realistically, when the saving is actually being realized on only the total of new type channels which will be installed within the next few years. It is hoped particularly that the article effectively emphasizes Mr. Kettering's basic lesson and alerts the reader to other potential opportunities.

Acknowledgement

The author wishes to acknowledge the courtesy of Schauer Manufacturing Corporation in furnishing the illustrations, Figures 11 to 15 inclusive, which are reprinted with their permission.

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Harley M. Ward joined the staff of the Central Office Engineer in 1921 after graduation from Ohio State University with the degree of B.E.E. He was awarded the degree of E.E. by that University in 1932, in recognition of his work on telegraph power plant design, particularly that in connection with the 60 Hudson Street office. He continued to engage in power engineering and development of power equipment for both land-line and cable offices, automatic and mobile emergency units, "continuous" power plants for relay and terminal stations on the original New York–Washington–Pittsburgh and subsequent Pittsburgh-Chicago extension of the Western Union microwave system. He is a Licensed Professional Engineer, a member of Sigma Xi and Eta Kappa Nu. He recently retired for reasons of health.